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Is Danish Venison Production Environmentallly Sustainable?

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Is Danish venison production environmentally sustainable?

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Executive summary

The guidelines for New Nordic Diet recommends that Danes reduce their consumption of meat by 35 %, and take 4 % of their meat as venison, since venison is *presumed* to be healthier, more palatable and more environmentally sustainable than meat from domestic animals. Presently Danes consume only 0.8 % of their meat as venison, and the consumption is very unevenly distributed; most hunters keep the main portion for themselves. A total of 2.6 million wild animals are reported shot by hunters each year in Denmark, and the possibility for increasing Danish venison production is limited, considering sustainable nature conservation at the limited area not already occupied by buildings and roads or exploited by agriculture.

The assumption that commercially produced venison is more environmentally sustainable than comparable industrial meat is rejected by the analyses in this report. Production of wild boar venison impacts the *overall environment*, characterized by i.e. monetizing and summing up 15 environmental impact potentials, twice as much as the closest reference meat type, i.e. pork; Production of wild boar meat impacts *global warming* 3 times more than pork. Production of duck meat impacts the *overall environment* 19 times more and pheasant meat 61 times more than chicken meat. Production of duck meat and pheasant meat impacts *global warming* 11 respectively 47 times more than chicken.

On the other hand, commercially produced meat from red deer, roe deer, fallow deer impacts the *overall environment* by respectively 10 %, 15 % and 16 % of the impact caused by beef production. The three deer species cause impacts ranging from 21 % to 62 % of the *global warming* impact of beef. But beef has the highest environmental impact burden of all meat types (when *using high-end impact values for beef as in this report)*, 12 times larger than pork, and in terms of global warming 14 times larger than pork; and beef is of course only *one* possible reference meat to deer meat. From the point of view of environmental impact it is recommended to eat deer rather than beef, but pork rather than wild boar, and chicken rather than mallard or pheasant. And pork or even better chicken should be preferred over deer meat in terms of both the *overall environmental impact* and *global warming*. But perhaps dear meat is *not* better than beef, as this depends on the numbers used to characterize the impact of beef.

This study found that a surprisingly large mileage is covered by hunters in relation to transport. But the largest environmental impact in the whole life cycle of venison production is caused by feed/fodder. At the same time this is the most uncertain data, since it remains to be better quantified how much feed deer take from farmers' fields, and how much they damage by trampling and disturbing crop growth and development. The supplied feed and fields planted for the benefit of wildlife and feeding off farmers' fields are all included in this study with the best available data. For roe deer meat the environmental impact of feed made up 60 % of the overall environmental impact of roe deer meat. For pheasant meat it was 95 %. Finally it should be mentioned that venison may not always be free of antibiotics, coccidiostats and heavy metals.

Dansk resumé

I retningslinjerne for Ny Nordisk Hverdagsmad anbefales danskerne at nedsætte deres kødforbrug med 35 %, og at 4 % af kødindtaget er vildtkød, fordi dette *antages* at være sundere, mere velsmagende og bæredygtigt end kød fra husdyr. I dag er kun 0,8 % af danskernes kødkonsum vildtkød, og tilgængeligheden af vildtkød er meget ulige fordelt; jægerne beholder hovedparten for sig selv. Danske jægere nedlægger i alt 2,6 millioner stykker vildt i Danmark om året, og muligheden for at øge dansk produktion af vildtkød er begrænset, da der er grænser for bæredygtigheden af større populationer på det beskedne areal der ikke er bebygget eller anvendes til trafik og jordbrug.

Påstanden, at kommercielt tilgængeligt vildtkød (købt i forretninger eller spist på restaurant) er mere bæredygtigt end sammenligneligt industrikød, afvises af analyserne i denne rapport. Produktion af vildsvinekød belaster *det samlede miljø*, beregnet ved monetarisering og sammenregning af 15 miljøpåvirkninger, dobbelt så meget som den nærmeste type referencekød, svinekød. Med hensyn til *global opvarmning*, så er vildsvinekød 3 gange så belastende som svinekød. Produktionen af andekød belaster *det samlede miljø* 19 gange så meget, og produktion af fasankød 61 gange så meget som kyllingekød. Andekød og fasankød belaster den *globale opvarmning* henholdsvis 11 og 47 gange så meget som kyllingekød.

På den anden side belaster krondyrkød, rådyrkød og dådyrkød kun *det samlede miljø* med henholdsvis 10 %, 15 % og 16 % af oksekøds samlede miljøbelastning. Hvad angår *global opvarmning*, så er kød fra de tre hjortearter 21 – 62 % så belastende som oksekøds klimabelastning. Men oksekød tegner sig da også for den højeste *samlede miljøbelastning* af alle kødtyper, især når vi som i denne rapport *anvender de højeste tal for oksekøds belastning*; 12 gange højere end svinekød. For *klimabelastning*, 14 gange højere. Fra et miljømæssigt synspunkt bør det derfor overvejes at spise hjortekød frem for bøf, men svinekød snarere end vildsvin, og kylling hellere end and eller fasan.

Dog bør svinekød, eller endnu bedre kylling, af miljø- og klimamæssige hensyn foretrækkes fremfor hjortekød. Men måske *er* hjortekød i virkeligheden *ikke bedre* end bøf, da det afhænger af hvilke tal, der anvendes til at karakterisere bøfkøds miljøbelastning.

Analysen fandt en overraskende stor kørsel forbundet med jægere og jagt. Men den største miljøpåvirkning i hele vildtkødproduktionen måtte tilskrives dyrenes fødeindtag. Imidlertid hviler oplysningerne om fødeindtag på et relativt usikkert datagrundlag, eftersom der endnu ikke findes tilstrækkeligt gode data for, hvor meget foder dyrene tager fra bondens mark, og hvor meget de ødelægger ved nedtrampning og forstyrrelse af afgrødernes vækst og udvikling. Såvel udbringning af foder, anlagte vildtagre og foragering på bondens mark er medregnet i denne rapport med de bedst tilgængelige data. For rådyrkød er miljøbelasningen forbundet med fødeindtaget 60 % af rådyrkødets samlede miljøbelastning; for fasankød er det 95 %. Til slut skal det nævnes, at man ikke kan regne med, at vildtkød altid er fri for antibiotika, coccidiostater og tungmetaller.

1. Introduction

It is a popular notion in Denmark that we should include more ingredients in our diet that are gathered, caught or hunted in nature rather than bred, grown and harvested on farmed fields, and in stables and waters. These new ingredients include commodities like seafood, seaweed, mushrooms, herbs and *venison*, i.e. meat from free-ranging wildlife in Denmark. In the recommendations for the New Nordic Diet, the Danish consumers are, among other recommendations advised to consume 35 % less meat, *with more than 4 % of the consumed meat being venison* (Meyer et al. 2011). But it is doubtful that Danish venison production will be able to support that goal. The "wild" ingredients in a modern diet are in general *assumed* to be both healthy and environmentally sustainable. But is this always true? More research is needed.

The present report seeks to answer the question: *'Does venison have less impact on the environment than the meat from domestic animals they replace'*. Six types of venison will be considered (Figure 1):

Figure 1 The six species considered in this study. Photos: From the web.

red deer

roe deer

fallow deer

wild boar

mallard

pheasant

2. Venison versus conventional meat from domestic animals

Danish meat consumption has doubled over the past 50 years and is currently among the highest in the world. A reduction in meat intake from mammals and birds could in itself improve public health, and at the same 'make room' for more fish, mushrooms and wild plants, fruit, whole grain products, vegetables and legumes in our diet – items that all have a documented positive effect on our health (Meyer et al. 2011).

Since meat is also among the most environmentally harmful foods (Steinfeld et al. 2007, Saxe 2014), the *New Nordic Diet* developed in the OPUS research project (2009-2013) recommends that Danes reduce their meat consumption by 30-40 %, and that the need for proteins are covered by alternative, less environmentally harmful sources (Meyer et al. 2011). Presently, Danes consume 138 g meat/day; OPUS' New Nordic Diet contains 85-100 g.

Industrial farming of meat, as it traditionally takes place in most industrialized countries is environmentally harmful because of the very large demand for complete feed, fossil energy and adjuvants such as pesticides and chemical fertilizers (Saxe et al. 2013, Saxe 2014). Going from an average Danish diet to the New Nordic Diet the associated global warming potential is reduced by one third (Saxe 2014). Animal husbandry is globally responsible for 18 % of greenhouse gases caused by our civilisation (Steinfeld et al. 2006).

The New Nordic Diet, as defined by the OPUS project recommends that we eat a minimum of 4 gram venison per day (Meyer et al. 2011). Meat from animals that live and forage in the wild is considered to be healthier than meat from domestic animals. Venison typically contains less fat, and has a healthier combination of fatty acids with the level of saturated fatty acids reduced 2 to 3-fold, and with more polysaturated fatty acids. Furthermore, venison contains significantly more n-3 fatty acids than conventional meat (Cordain et al. 2002).

It is estimated that at present Danes consume an average of 0.8 g venison per day mostly as red deer, row deer, partridge, pheasant, mallard and hares.

The Danish Academy of Hunting (2014) estimates that the annual volume of Danish venison is less than 500 g per Dane per year including waste, or approximately 1.4 g venison per Dane per day. But the goods are very unevenly distributed. Hunters take the major share of Danish venison (there are approximately 100,000 active hunters in Denmark), leaving the rest of the Danish population (5.6 million people) with next to nothing. But no matter who consumes the Danish venison, and who is left to consume imported venison or conventional meat, if the objectives of the New Nordic Diet should be met, it is highly relevant to know more about the environmental impact of Danish venison production (allocated to species). The environmental impact of Danish venison varies from one species to the next, from region to region, and by the degree to which the animals are truly living in the 'wild'. Pheasants and mallards are reared and released for hunting (though many escape into the wild), wild boars have to be kept inside electric fences and must be fed, while the deer species typically run wild, but are often fed and feed on farmers' crops which they also trample and disturb. In this project we exclusively study *Danish* venison, not imported venison; and the scope is limited to commercially available venison from Klosterhedens Vildt abattoir.

A life cycle assessment of venison in Denmark has never before been carried out, but was envisioned and initiated under the OPUS project (2009-2013). Environmental advantages of venison over meat from domestic animals were anticipated. By substituting some of our conventional meat intake with venison, significant savings in feed and associated use of agricultural area, energy and transport was expected. It was assumed that wildlife as the source of venison primarily live off areas not occupied by agriculture. This, however was wrong! However, wildlife is beneficial to our positive experience of nature, and venison takes a special position in gastronomy with its aromas, colours, tenderness and taste caused by the at least partially natural living of most wild game, as opposed to meat from domestic animals. Those were the motives for recommending an increased content of venison in the New Nordic Diet.

The national Danish game act establishes that hunting must be performed with due respect for ecological and ethical principles – and be *sustainable* (Christensen et al. 2014). Sustainability in this context means that wildlife populations may not decline due to hunting and that the wildlife may not be ousted from their natural habitats for extended periods due to disturbances caused by hunting. In both instances this depends on the intensity of hunting. In other words, there is an upper limit to hunting if the carrying capacity of the ecosystems is to be respected. When the need for hunting regulations is deliberated, the conclusions depend on the number of hunters, how much they each kill, and the general health and development of the natural populations. In the case of mallard, pheasant and wild boar a natural population is an imaginary concept since these populations are artificially boosted or kept under control for the sole benefit of hunters and hunting. For further general information on hunted Danish wildlife, see Bregnballe et al. (2003).

In terms of monetary resources it is estimated that it costs the hunter an average of 1,000 D.kr. to bag a single animal (Dansk Jagtakademi 2014). There are many entries in this account, some of which are not even resource demanding (e.g. hunting leases). But as will be shown in this report, there is a large amount of energy consumed to bring home the venison (driving), and a surprisingly large amount and variety of fodder involved, and a not unimportant need for establishing and maintaining infrastructure relevant to hunting. All this causes environmental impact associated with venison production that is neither internalized in the hunters' nor in the consumers' cost of venison.

This study will estimate if venison is more or less environmentally harmful than meat from comparable domestic animals. The environmental impact is not reflected in the price we pay for either venison or industrial meat from domestic animals as it ought to be according to Principle 16 in the Rio Declaration (1992). Hunters typically pay to kill a piece of wildlife, and mostly the venison is just a by-product.

Wildlife is intuitively expected to be free of medication. The truth, however, is that certain quantities of coccidiostats and/or antibiotics are used for the breeding of e.g. game birds. At Bakkegårdens vildtopdræt, from where the mallards to Frijsenborg studied in this report originated are preventively treated with coccidiostats. The borderline between wild and domestic animals is, also in this respect rather diffuse.

Heavy metal like lead that may accumulate in the food chain is another potential environmental and health problem with venison. Heavy metal residues from cartridges used to hunt pheasants and mallards, and lead from riffle bullets used to hunt deer are examples of this (Kanstrup 2009, Danish Academy of Hunting 2014). Riffle bullets used in Denmark are often lead free, but there is no reliable evidence to what extend this solves health related problems with venison. Potential problems with coccidiostats, antibiotics, and heavy metals are *not* studied in this report, but could add further to the environmental and health impacts of venison; however, neither is it taken into account in the calculations of environmental impact of industrial meat which makes the comparison fair.

3. Methods

Klosterhedens Vildt [1], game keepers, huntsmen, traders and a wide range of businesses and experts at private and public institutions were consulted to collect relevant life cycle inventory (LCI) data on game management, hunting, transport, processing, packaging, materials, energy, waste and distribution.

Production data for industrially produced meat from domesticated animals can be found in databases such as ECOINVENT[2] and LCAFOOD[3], but there is no information of the environmental impact of venison, which will be provided in this study. The environmental impact of venison production was analysed

[1] http://www.klosterhedens-vildt.dk/page.asp?pageid=1112&pagename=Om+os&parent=1286#
[2] http://www.ecoinvent.org/database/ecoinvent-version-3/
[3] http://www.lcafood.dk

applying Life Cycle Assessment (LCA) using the SIMAPRO 8.04 LCA software[4] and associated databases. The choice of environmental impact categories were chosen with the objective of representing as many aspects of environmental impact as possible given by a single method. A consequential LCA approach was applied since LCA was used for analysing different agricultural production systems to find answers for policy-making or strategic environmental planning. Accordingly, system expansion was applied for co-product handling to fully account for the different functions of the analysed farming systems.

The STEPWISE[5] 1.05 method (Weidema 2009) was chosen as the most appropriate LCA method with the option of monetizing. STEPWISE analyses the environmental impact in terms of 16 environmental impact categories[6] associated with all activities, energy- and resource consumption from soil-to-supermarket or restaurant. The broad spectrum of environmental impacts are summarised in a common expression by monetizing 15 of the studied environmental impact categories, thus revealing the socioeconomic cost associated with the environmental impact of Danish venison production within the scope of this study.

Furthermore, monetizing makes it possible to compare the environmental impact of widely different products and services. The socioeconomic cost of the environmental impact of the six types of venison and comparable industrial meat types is thus obtained for direct comparison of the overall environmental impact of relevant meat types. Venison production from red deer, roe deer, and fallow deer are mainly compared with beef production, and wild boar production with pork production. Mallard and pheasant are compared with chicken production.

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[4] http://www.pre-sustainability.com/simapro

[5] http://www.sciencedirect.com/science/article/pii/S0921800908000475

[6] Human carcinogenic and noncarcinogenic toxicity [chloroethene-equivalent (eq)], respiratory inorganics (particulate matter with a diameter of ≤2.5 mm), ionizing radiation (Bq, the SI-derived unit of radioactivity, C14-eq), ozone layer depletion (chlorofluorocarbon 11), aquatic and terrestrial ecotoxicity (chloroethylene triethylene glycol-eq), nature occupation (agricultural land), global warming (CO_2-eq), acidification (area unprotected ecosystems), aquatic (NO_3-eq) and terrestrial (area unprotected ecosystems) eutrophication, respiratory organics (person · ppm^{-1} · h^{-1}), photochemical ozone effects on vegetation (m^2 · ppm^{-1} · h^{-1}), nonrenewable energy (MJ primary), and mineral extraction (MJ extra).

3.1 Life cycle inventory analysis

The basis for a reliable LCA of venison is detailed Life Cycle Inventory (LCI) data involving a complete inventory from 'nature/soil to customer' or – 'cradle-to-table' for the product systems. Inventory flows include inputs of raw and processed materials, energy and water, and releases to air, land and water. To develop the inventory, a flow model of the natural/technical system was constructed using data on inputs and outputs. The input and output data needed for the construction of the model were collected for all activities within the system boundary, including the complete supply chain, referred to as inputs from the technosphere. The data must be related to the functional unit defined in the goal and scope definition of the LCA (section 3.2).

Inventory flows can number in the hundreds depending on the system boundary. Data in this study were – as is typical – collected through survey questionnaires where care was taken to ensure that questionnaires were completed by a representative sample of producers, leaning toward neither the best nor the worst, and fully representing any regional differences due to energy use, infrastructure, hunting and hunters or other factors. A 15-page questionnaire was forwarded to relevant people ahead of a series of interviews. The extensive notes from these interviews were processed and returned to the people who were interviewed. After communication back and forth the results obtained formed the basis of a complete LCI (Life Cycle Inventory) of Danish venison production at Klosterhedens Vildt abattoir in Jutland. The study focused on the activities in 2010/11 considered to be representative of the venison production at *Klosthedens Vildt abattoir* even today. The LCI was carried out in three steps: (1) from animal birth to slaughter, (2) the slaughter and packaging processes at the abattoir, and (3) from slaughter to retail. The first step was divided into (a) infrastructure, (b) feed and (c) hunters and hunting.

The questionnaires covered the full range of inputs and outputs, which is aiming at accounting for 99 % of the mass of the products, 99 % of the energy used in their production, and any environmentally sensitive flows, even if they fell under the 1 % level.

The LCI was performed separately for venison production from each of the six investigated species – red deer, roe deer, fallow deer, wild boar, mallard and pheasant. The total meat production at Klosterheden Vildt is given in Table 1, data providers and consultants who were interviewed are given in Figure 2, and the flows were summarised as exemplified for red deer in Figure 3. In this study all contributions to environmental impact were included for both venison and industrial meat, 'from soil to consumer', making all comparisons realistic and fair.

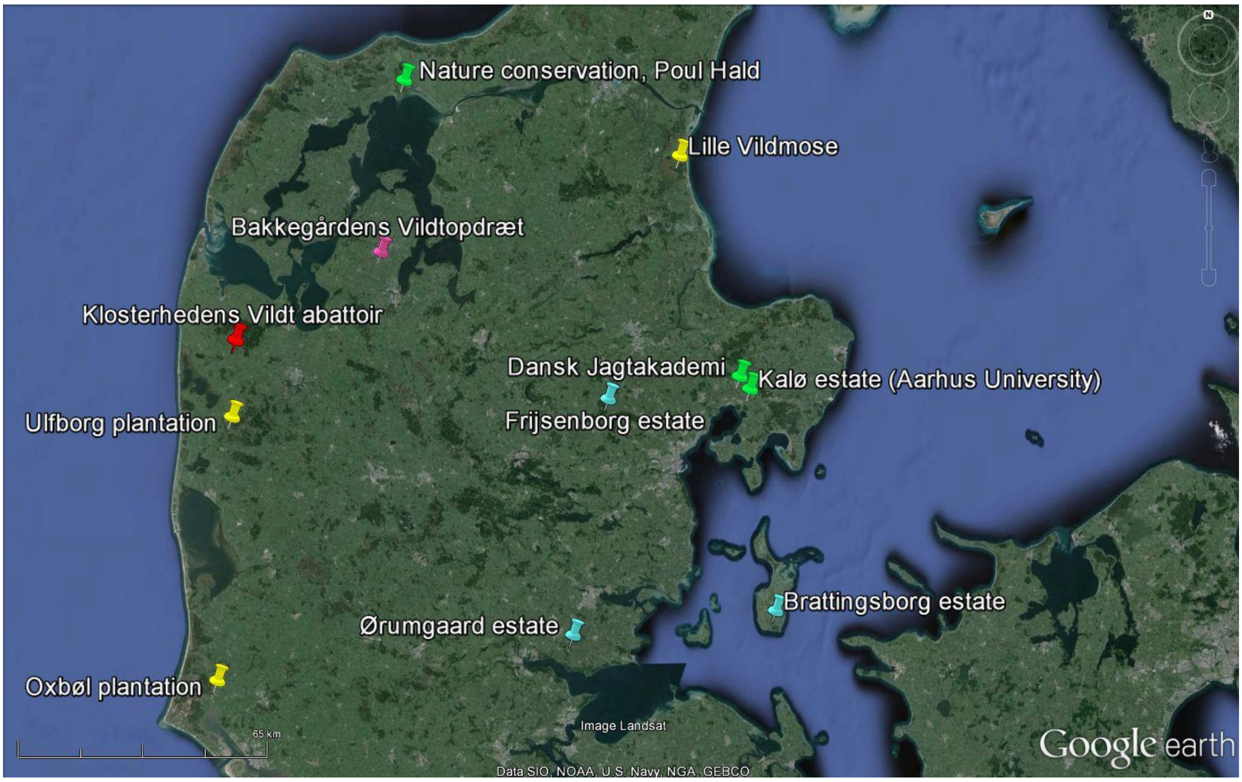
3.2 Goal and scope

The goal of this study is to provide information to hunters, nature managers, distributors, retailers, consumers – and to the project sponsors (15 Juni Fonden, Nordea Fonden) – on the sustainability of Danish venison production at *Klosterhedens Vildt*, one of the two major Danish abattoirs specialising in venison production, and its contracted suppliers.

For all six species of hunted wildlife, the functional unit (FU) is 1 kg of venison meat commercially produced and sold for consumption. Venison taken by the hunter for his/her private consumption is not included since it is not comparable to the chosen references in this study, i.e. meat from domestic animals sold to consumers in retail shops or consumed at restaurants.

Furthermore, it is part of the scope of the present study that it only deals with venison from Jutland (The Western Danish 29,652 km^2 peninsula + Samsø 114 km^2), and only with meat produced at *Klosterhedens Vildt* abattoir during 2010/11 and 2013/14 (system boundaries). It is assumed that the studied venison production is a reasonably good estimate of the overall Danish commercial venison production, though the environmental impact may differ from venison produced on Zealand (Eastern Denmark), and to some degree (discussed later) from locally hunted and consumed meat. Future studies may fill these gaps.

Figure 2 The data providers and consultants in Jutland (Western Denmark) included staff at two plantations (Ulfborg/ Klosterhede and Oksbøl), at Aage V. Jensen Naturfond's Nature Conservation and Wild Life Protection area (Lille Vildmose), at three estates (Frijsenborg, Ørumgaard and Brattingsborg), and four consultants Poul Hald (former vice director of the Danish Society for Nature Conservation), Tommy Asferg and Peter Sunde (Aarhus Universitet at Kalø), and Niels Kanstrup (Dansk Jagtakademi), one producer (Bakkegårens Vildsopdræt, Frederik Thomsen), and *Klosterhedens Vildt abattoir* (Charlotte Renberg).



3.3 Allocation of impacts

How much of the environmental impact should be allocated to each aspect of venison production? For deer and wild boar it was decided to be first and foremost a question of '*venison as a food source*'. Secondly, there is '*the joy of hunting*' countered by *the ´disturbance´ by hunters* associated with venison production. And thirdly there is the aspect of '*nature management*'; without hunting, some nature managers claim, the Danish deer populations could 'run wild' resulting in a loss of crops from farmed land and possible deteriorating health of the deer populations if reaching starvation. Since population control could be carried out more efficiently than hunting, this aspect does not have high priority. For the deer species, it was decided that 100 % of the impact should be allocated to the meat value, 0 % to the 'joy of hunting'" and 'disturbance', and 0 % to nature management, since the latter impacts are subjective ('immaterial/intangible goods') compared with the physical and accountable impacts of hunting. The immaterial aspects of Danish nature are discussed in reports as for example 'Friluftslivets Nationaløkonomiske Fodaftryk' (Jacobsen et al. 2014).

For mallards and pheasants the primary goal is more likely 'the joy of hunting' (and the positive social impacts associated with this) than the food value, and for nature management it is more a question of adapting nature to the hunting in terms of for example artificial lakes and 'put-and-take' birds. However, for the birds it was nevertheless decided to allocate 100 % of the impact to the meat value, while 0 % was allocated to the 'joy of hunting' partly because this is difficult to assess and partly because it is countered by people who 'oppose' hunting, especially pheasant hunting; Zero percent was allocated to nature management since there are both positive and negative effects which are difficult to quantify in an objective way. So overall, this report focuses on estimating the direct environmental impacts of hunting.

There are several sources of uncertainty in the calculations of environment-tal impact of venison production; the major source being the estimation of the feed that deer take from farmers' fields and the impact on plant growth and development by trampling. This is at the same time the largest single source of environmental impact of free ranging deer species. Estimates of farmers' field foraging was suggested by Poul Hald who has a lifelong experience in this matter, partly based on stomach content of dead deer (Petersen, 1998). Other methods include several informal statements by local farmers[7]. Future methods may include GPS-tracking of deer. A report by Kanstrup et al. (2014) describes feeding patterns of red deer and other deer species. In conclusion,

[7] E.g.: http://www.jlbr.dk/Nyheder/AlleNyheder/Kronvildtet_hoester_afgroederne_08112012.htm

the best available data on wild life feeding was applied in the analyses of environmental impact of venison production given in this report.

4. Results

The hotspots for environmental impact of venison include feed/fodder, infrastructure, and the hunter/hunting. The latter include an unexpected high mileage travelled in private cars.

4.1 Venison production at Klosterhedens Vildt abattoir

Table 1 gives an overview of the volumes of venison produced in 2010/11 and 2013/14 at Klosterhedens Vildt abattoir. In 2013/14 the production of red deer, mallard and pheasant venison went up. The LCI will be examined for each animal species below, but only data from 2010/11 are included in this study.

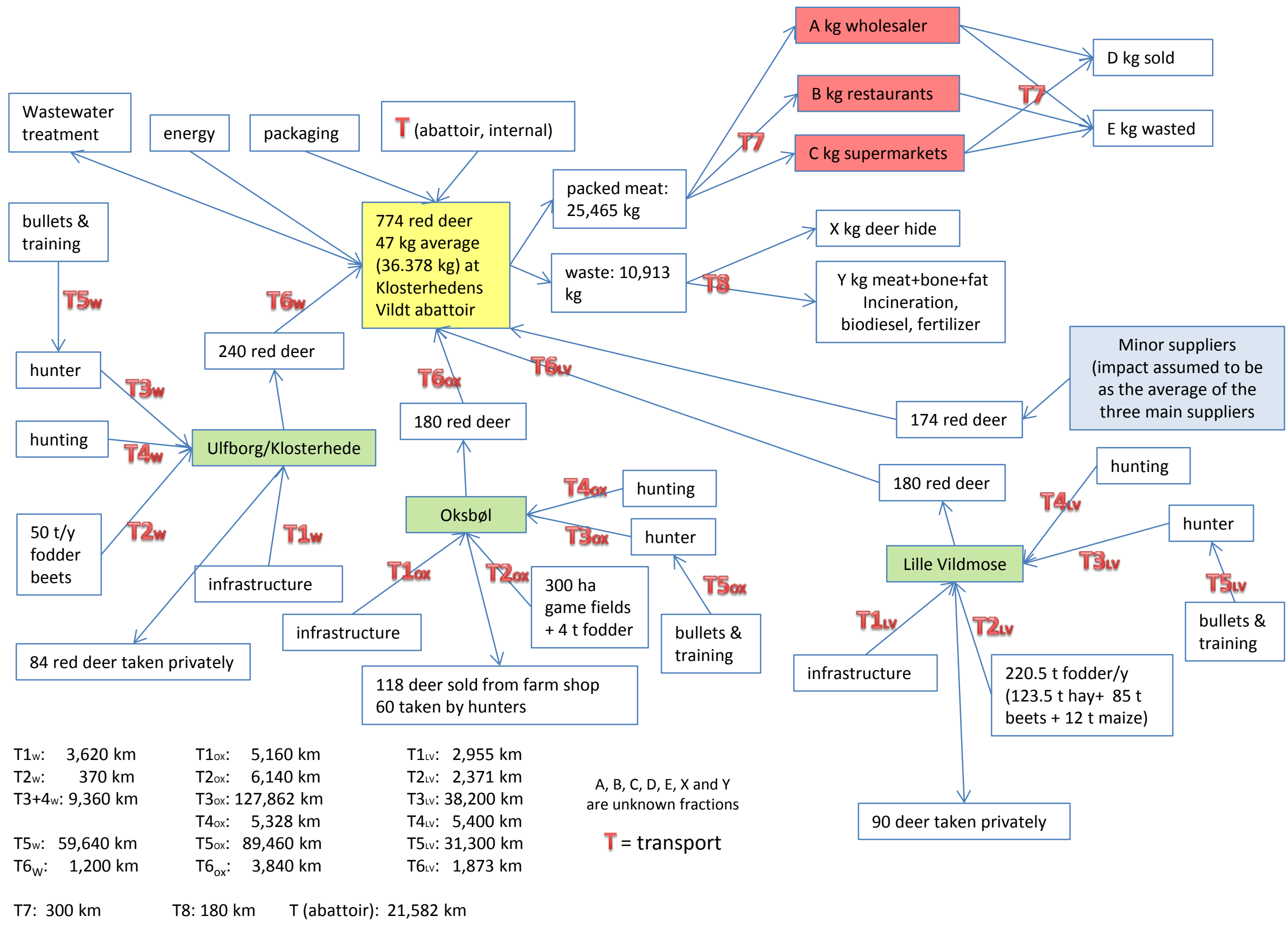
Table 1 Meat from six species of venison processed at the Klosterhedens Vildt abattoir during two years, 2010/11 and 2013/14 (marked in grey).

	2010/11					2013/14			
Species	**Number of animals**	**Tot meat weight, kg**	**Ave per animal**	**Net kg produced**		**Number of animals**	**Tot meat weight, kg**	**Ave per animal**	**Net kg produced**
Red dear	774	36,378	47.0	25,465		854	30,744	36	27,055
Fallow dear	140	4,340	31.0	3,038		139	3,406	24.5	2,997
Roe deer	252	2,873	11.4	2,011		205	1,845	9	1,624
Wild boar	174	4,727	27.2	3,545		160	2,924	18,275	2,485
Mallard	3,082	2,620	0.75	1,965		6,058	5,452	0.75	4,089
Pheasant	12,721	8,269	0.85	1,819		14,069	9,567	0.85	4,444
Total				**37,843**					**42,694**

4.2 Red deer

Figure 3 shows a LCI flow chart for commercial production of red deer venison at Klosterhedens Vildt abattoir from soil to seller (shops and restaurants). In this study red deer are supplied to Klosterhedens Vildt abattoir from three areas: Two Danish Nature Agency plantations in West Jutland Ulfborg/Klosterhede and Oksbøl, and Aage V. Jensen Naturfond's nature conservation and wild life protection area *Lille Vildmose* in North Eastern Jutland. Each of these data suppliers provided distinctive LCI data.

Figure 3 Life Cycle Inventory (LCI) of red deer venison production during 2010/11 involved 3 main suppliers (green boxes) that covered 78 % of the red deer venison produced by Klosterhedens Vildt abattoir. The environmental impact of the minor suppliers (blue box) was estimated as an average of the main suppliers. The flow indicated in the figure below includes many types of and occasions for transport (T) which has environmental impacts, and for each supplier furthermore the environmental impact associated with (1) feeding off farmers' fields, (2) fodder delivered to the deer, (3) infrastructure, and (4) hunter and hunting. For all suppliers a share of the abattoir impact, waste and transport to the consumer is added to reach the overall environmental impact.



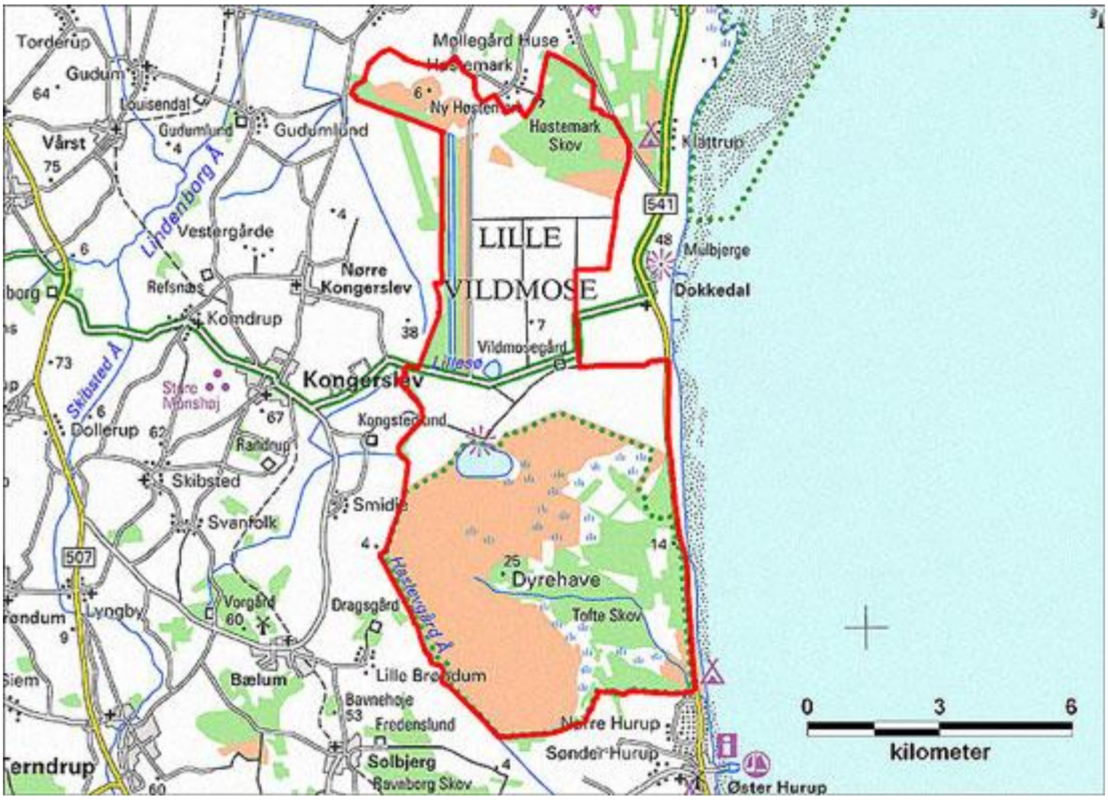
4.2.1. Lille Vildmose (data providers: Jacob Palsgaard Andersen and Jacob Skriver)

The areas at Lille Vildmose supporting game management and hunting include Høstemark forest and Tofte moor and forest (Figure 4). Two venison species are roaming these areas: red deer and wild boar.

Infrastructure

The red deer population in Høstemark is fenced in by a 9 km fence established in 1930 (Figure 4).

Figure 4 Aage V. Jensen Naturfond's nature conservation and wild life protection area *Lille Vildmose* in North Eastern Jutland.



The durability of the fence is 25 years and it is successively being replaced with an average of 360 m fence per year. The red deer and wild boar in Tofte are kept inside a 25 km fence of the same type as in Høstemark but established in 1906-08. From the beginning there were only red deer behind the fence, while wild boars were added in 1929. The old fence is being successively replaced with an average of 1,000 m fence per year. The 1,360 m of fence weighing an estimated 2,720 kg was mounted with 13,040 cramp irons of 5 g each, giving a total of 2,916 kg galvanized iron. In addition, 600 km tractor transport with a post drill was applied to re-establish the posts.

Workers' driving for fence replacement was estimated at 1,800 km transport in passenger cars and regular inspection of fences required 525 km transport by passenger car or ATV; a total of 2,325 km. According to meat weight a share of 1,860 km was allocated to red deer and 465 km to wild boar. Delivery of fence parts involved 250 km transport using a small truck, while disposal of posts involved 60 km transport using a large truck, and disposal of scrap iron involved 25 km transport using a large truck. The 250 km and 85 km in small/large trucks were allocated to red deer hunting only.

There are 90 shooting towers in Lille Vildmose build from larch/douglas fir weighing an estimated 100 kg each. The average bulk density of these tree species is 0.56 kg/m^3. Shooting towers last for 15 years, so that the annual requirement for new wood is 1.07 m^3 wood per year. Each shooting tower was estimated to be constructed with 1 kg nails, screws and bolts, i.e. 6 kg to be applied every year. 2/3 of the environmental impact of replacing shooting towers was allocated to red deer hunting and 1/3 to wild boar. Driving a tractor with a trailer to replace shooting towers was estimated at 120 km, allocated as 80 km for red deer and 40 km for wild boar, and driving to waste dump the same mileage and allocation but using a small truck.

The waste from hunting was picked up by DAKA six times per year, where the data for waste relevant to red deer sold to Klosterhedens Vildt abattoir was 40 km truck carrying 1 t of waste.

Carcasses that were sold to Klosterhedens Vildt were deposited in coldrooms with an annual power consumption of 22,000 KWh 2/3 of which was allocated to the commercial meat production, 2/3 to red deer and 1/3 to wild boar, and the rest for locally sold meat. The red deer were sent to the abattoir six times per year, involving transport of 312 km roundtrip using a delivery van.

Calculations
Red deer fence: An average of 1,360 m fence replaced each year includes 340 3 m round Rubinia (Acacia) posts (without need for chemical preservation) ø=0.15 m diameter = 340 × 3 m × 3.1416 × 0.075 m × 0.075 m = 18.0 m^3 rubinia. Plus 1020 thinner 3 m oak posts ø=0.05 m = 1020 × 3 m × 3.1416 × 0.025 m × 0.025 m = 6.0 m^3 Rubinia. Total = 24 m^3 Rubinia. The environmental impact of this was calculated as 'Sawnwood, hardwood, raw, air dried {RER}| market for | Conseq, U'. 2,785 kg fence and cramp irons was calculated as 'Chromium steel pipe {GLO}| market for | Conseq, U'. Driving for replacement and inspection of fences was calculated as 'truck < 10 t, 80 load, empty return, euro2, economic alloc.'.

Electricity: The environmental impact of power consumption by electric fences and coldrooms was calculated as 'Electricity, medium voltage {DK}| market for | Conseq, U'.

Wood for shooting towers: The environmental impact of shooting tower replacements was estimated by 'Sawnwood, hardwood, raw, air dried {RER}| market for | Conseq, U' for wood, and 'Chromium steel pipe {GLO}| market for | Conseq, U' for metal parts.

Transport to abattoir: 1,872 km driving with 1.41 t red deer (Table 1) calculated as 'tkm Delivery van <3.5t (of project LCA Food DK)'.

Fodder

Neither the red deer nor the wild boar can feed on the surrounding farmers' fields since they are fenced in. In exchange, the wild life managers feed the animals with 1,350 units of 50 kg wrapped hay bales per year, 160 units 350 kg of large hay bales, 80,000 kg maize, and 85,000 kg fodder beets per year. The red deer was estimated to consume all the hay and beets while the wild boars consume 85 % of the maize.

Calculations. *Fodder production*: the environmental impact of 1,350 × 50 kg hay + 160 × 350 kg hay = 123.5 t hay calculated as 'Swiss integrated production, intensive {CH}| production | Conseq, U, Ecoinvent 3' + 80 t maize (12 t for red deer and 68 t for wild boar) calculated as 'Maize grain, Swiss integrated production {CH}| production | Conseq, U' + 85 t fodder beets calculated as 85 t 'Fodder beets cleaned, consumption mix, at feed compound plant/NL Economic'. *Fodder delivery*: Hay and fodder beets were produced in the vicinity of the park and assumed delivered by tractor with trailer: 208.5 t × 20 km (roundtrip, 42 times) calculated as 'Transportation, tractor and trailer, agricultural {CH}| processing | Conseq, U'. Maize was delivered by truck from Vendsyssel and stored locally in a silo: 80 t × 80 km (roundtrip, 10 times) calculated as `Transportation, truck <10t, EURO2, 80%LF, empty return/GLO Economic, agri-footprint - economic allocation'. *Fodder distribution*: 288.5 t fodders were distributed in Høstemark in the North and in Tofte forest in the South using a small tractor with trailer consuming a total of 1,500 l diesel/year. Assuming a mileage of 1.24 km/litre diesel, a tractor with trailer would have covered 1,860 km in a year. Assuming the distribution trips averaged 16 km there would be 116 trips each winter carrying 2.5 t fodder of three types to two forest areas = 4,650 tkm, of which 76 % was for the red deer, and 24 % for the wild boars (based on the fodder ratios).

Hunter and hunting

The 'average' hunter is roughly estimated to drive 10 times, 30 km roundtrip for game licence training (Danmarks Jægerforbund, Rønde) and the licence is estimated to have an average active life time of 10 years (some never use it, some use it for life). Before each hunt the average hunter is estimated to travel 100 km roundtrip to a preferred shooting range test shooting his/her riffle an average of 48 shots using bullets with an average weight of 12 g consisting of 2.4 g brass, 8.4 g lead and 1.2 g tungsten. It is estimated that the hunter drives 50 km roundtrip to buy or look for equipment three times a year. For each animal a minimum of two bullets are fired. It took an estimated 180 hunters to shoot the 180 red deer at Lille Vildmose.

There were four categories of hunting at Lille Vildmose in 2010/11. Each contributed to the environmental impact of venison by the distance hunters travelled to reach Lille Vildmose, the distance covered during hunts, and the shells and equipment used by hunters.

Calculations. *Hunter:* 180 hunters drive 10×30/10 km to obtain their licence + 180×100 km to shooting ranges + 180 * 3 × 50 km to buy equipment = 50,400 km estimated as 21,700 km 4WD and 28,700 km passenger car per year. Only half of these mileages were allocated to red deer hunting or wild boar hunting, and the rest to other types of hunting conducted by the 180 hunters. This is divided between red deer and wild boar as 180:110 (animal kill ratio). Riffle bullets used in the red deer hunting where the animals are sold to Klosterhedens Vildt abattoir involve the use of an estimated (48+2)×180×5 g brass = 21.6 kg brass; 75.6 kg lead; 10.8 kg tungsten, calculated as 'Brass {GLO}| market for | Conseq, U', 'Lead {GLO}| market for | Conseq, U' and 'Copper {GLO}| market for | Conseq, U' (cobber impact values transferred to tungsten). These materials are also divided between the two species as 180:110.

1. *Single hunts*: 30 individual hunters from 'far away' shot 25 stags (males) over 30 individual days. The hunter only receives the head with antlers; the rest was sold to Klosterhedens Vildt abattoir. The park manager estimated that each hunter drove an average of 400 km roundtrip, some from Central and Southern Jutland and the island of Funen to reach Lille Vildmose: 6,000 km/year passenger cars + 6,000 km/year 4WDs.
2. *Regional hunters*: 40 man-days, regional hunters shot 25 does (females) and 25 fawns (calves); the red deer were sold to Klosterhede Vildt abattoir. The park manager estimated that each hunter drove an average of 150 km roundtrip to reach Lille Vildmose: 6,000 km/year in passenger cars.
3. *Local hunters*: 20 man-days, local hunters shot 20 does and 20 fawns over 20 days; the red deer were sold to Klosterhedens Vildt abattoir. The park manager estimated that each hunter drove 10 km roundtrip to reach to reach Lille Vildmose: 200 km/year in passenger cars.
4. *Mixed hunting*: Nine organized hunting parties with 10 participants each altogether shot 65 stags and 165 wild boar; the red deer and wild boar were sold to Klosterhede Vildt abattoir. The park manager estimated that the hunters arrived as 1.5 persons per vehicle coming from distant origins as far as Northern Zealand on average covering a 500 km return roundtrip, resulting in a total of 15,000 km driving in passenger cars and 15.000 km in 4WDs. Based on the number of killings, 2/3 of this driving was allocated to wild boar and 1/3 to red deer.

Driving during hunts: The accounted 180 hunter man-days of hunting are estimated to cover an average driving distance of 15 km roundtrip form the rendezvous site, which equals 2,700 km, assumed covered by passenger vehicles only. 2,400 km was allocated red deer hunting and 300 km was allocated wild boar hunting.

Hunt-helpers' driving: According to the park manager 25 helpers drove 40 km roundtrip to the rendezvous sites in passenger vehicles for each of 11 days = 11,000 km. Of this mileage 3,000 km was allocated to red deer hunting and 8,000 km to wild boar hunting (assuming battue).

In total the hunters at Lille Vildmose drove 6,000 km + 6,000 km + 200 km + 10,000 km = 22,200 km in passenger cars and 6,000 km + 10,000 km = 16,000 km in 4WDs associated with red deer hunting to and from the hunting rendezvous sites ($T4_{LV}$ = 38,200 km). Helpers accumulated 3,000 km driving to and from the hunting rendezvous sites relevant for red deer, and driving by all participants during hunts amounted to 2,400 km in passenger vehicles relevant for red deer, totalling 5,400 km ($T3_{LV}$) for onsite hunt related driving, totalling 43,600 km for red deer. Accordingly, 18,300 km was driven for wild boar (chapter 4.5). The environmental impacts of driving passenger vehicles was calculated as 'Transportation, passenger car, medium size, petrol, EURO 3 {RER}| transportation, passenger car, medium size, petrol, EURO 3 | Conseq, U' and impacts by 4WDs by 'Transportation, passenger car, large size, diesel, EURO 3 {RER}| transportation, passenger car, large size, diesel, EURO 3 | Conseq, U'.

According to the park manager 180 red deer were sold Klosterhedens Vildt abattoir and a further 1/3 of the total kill, i.e. 90 red deer were taken privately (i.e. not sent to the abattoir) on undesignated hunts.

4.2.2. Oksbøl (data provider: Kim Klitsgaard, Ole Knudsen, and Poul Hald)

The Oksbøl red deer reservation was in established in the 1940’s and covers 16,254 ha in South Western Jutland (Figure 5).

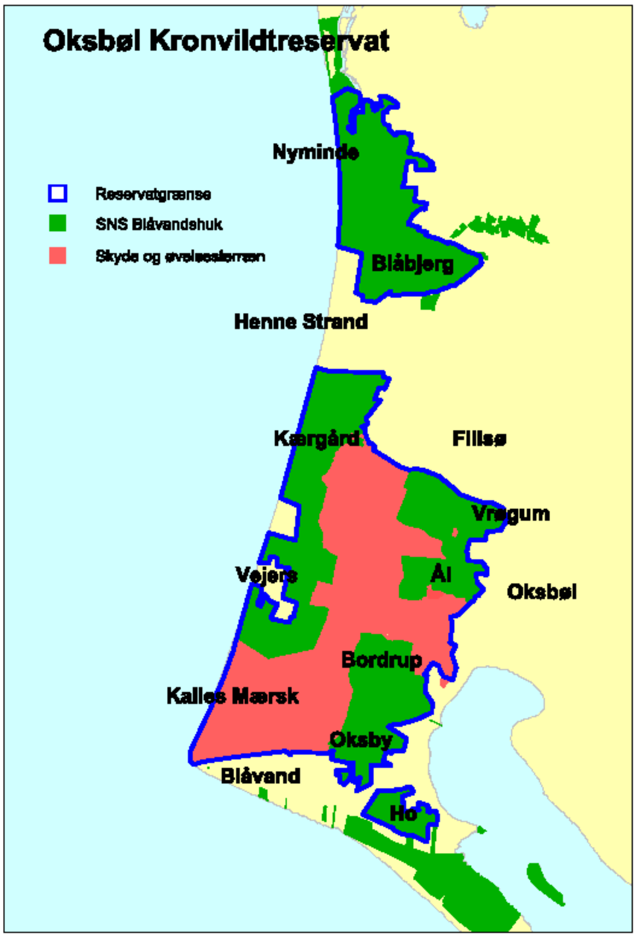


Figure 5 **The Oksbøl reservation. The blue lines mark reservation borders. The green areas are managed by the Nature Agency of the Danish Ministry of the Environment. The red area is a military practice and shooting terrain. The combined area is a designated red deer sanctuary. 1/3 of the area is used for military purposes – shooting and training exercises. Photo: Henrik Saxe.**

Oksbøl is a deer sanctuary, but not in terms of the deer not being hunted. But hunting is carried out according to the objectives and guidelines agreed between the two owners, the Nature Agency and the military. The area is a mosaic of the open military heath areas alternating with forested areas. This is ideal for all deer species that find food in the open areas and take cover in the dense forests. The main objective of the red deer conservation is to maintain a large, healthy population at a level where the animals can be day-active. Their number must not reach a level where the deer take too much fodder from neighbouring farmers.

Since the red deer may damage the farmers' crops by foraging and trampling, 300 ha grass-clover game fields are continuously being established scattered over the area managed by the Nature Agency. However, during dry summers the farmers' crops are more attractive than the Nature Agency's grass-clover fields since the sandy soil of the plantation easily dries out. Famers having fields up to 2 km from the reservation perimeter can file for compensation when deer cause crop loss. Furthermore, an overly large population of deer may threaten road safety in the area.

Red deer, roe deer and fallow deer are hunted in the Oksbøl reservation, but only red deer are sold to Klosterhede Vildt abattoir, and only as gutted and cleaned bodies. Oksbøl even has its own abattoir.

Infrastructure

Young broadleaf plantations on the Oksbøl areas that are managed by the Nature Agency are fenced to protect them from deer foraging. Management considers these a necessity whether there is hunting at Oksbøl or not, since there would in any case be a 'natural' deer pressure. However, since it theoretically is an alternative to eliminate the deer altogether, the fences are in this report viewed as a necessity both with respect to the young broadleaf trees and with respect to the significant deer population. The environmental impact of establishing and maintaining the fences are thus allocated with 50 % to each. The broadleaf trees partly serve the 'ecological development' of the area, and partly they are produced for profit. More reasons to allocate 50 % of the environmental impact of fencing to red deer is that they will feed on leaves of the broadleaf trees, beech nut and acorn once the fences are removed; and while some fences are damaged by storms, others are damaged by red deer trying to escape when hunted and then have to be re-established.

The fences are constructed with oak posts every 20 meter with four galvanized iron posts in between. 4,000 meter of fence is constructed annually, and its lifetime (iron posts are reused once) is 10 years after which the broadleaf trees are tall enough to withstand deer pressure.

The 4,000 m of fence estimated to weigh 2,400 kg was mounted on the wooden posts with 2,000 cramp irons weighing 5 g each and supported by 800 iron posts (used twice) weighing 11 kg each giving a total of 11,210 kg galvanized iron of which 50 % was allocated to red deer hunting and 50 % to reproduction of broadleaf trees. In addition 1,200 km tractor transport mounted with a post drill was applied to establish and remove posts over respectively 40 and 20 days. Regular inspection of fences involved driving an estimated 1,200 km, while driving to and from work for this task required 800 km transport in passenger cars; driving with the purpose of counting deer was estimated at 1,200 km per year. A total of 3,200 km. Delivery of fence parts required 400 km transport using a small truck, while disposal of iron posts and scrap iron required a further 200 km transport using a small truck. All these mileages were allocated with 50 % to red deer hunting. Old oak posts were left in the forest.

There are 65 shooting towers in Oksbøl build with larch/douglas fir timber weighing an estimated 200 kg each. The average bulk density of these tree species is 0.56 kg/m^3. Shooting towers last for 15 years, so that the annual requirement for new wood is 1.55 m^3 wood per year. Each shooting tower was estimated to be constructed using 1 kg screws and bolts, i.e. 4.3 kg to be applied every year. All shooting towers were allocated to red deer hunting. Driving a tractor with trailer to replace shooting towers was estimated at 120 km, and driving to waste dump the same mileage but in a small truck.

The waste from gutted red deer was picked up by DAKA 12 times per year, where the data for waste relevant to red deer sold Klosterhedens Vildt abattoir was associated with 40 km truck driving with 1 t waste. Overall, the estimated transport associated with the infrastructure $T1_{ox}$ = 5,160 km (Figure 3).

Gutted and cleaned carcasses that were sold to Klosterhedens Vildt were stored in coldrooms with an annual power consumption of 22,000 KWh, half of which was allocated to the commercial red deer meat production at Klosterhedens Vildt. The red deer were put in individual 100 g plastic bags and delivered to the abattoir 15 times during 2010/11, each roundtrip covering 256 km using a 4WD with trailer; $T6_{ox}$ = 3,840 km (Figure 3).

Calculations. *200 oak posts × 3 m × 15 cm ø = 10.6 m³ wood estimated as* 'Sawnwood, hardwood, raw, air / kiln dried {RoW}| market for | Conseq, U'. 12430 kg fence, iron posts and cramps was calculated as 'Chromium steel pipe {GLO}| market for | Conseq, U'. Establishing and removing posts involved driving 1,200 km tractor with drill, and half of this was allocated to red deer. Car with trailer was estimated as small van. The environmental impact of plastic bags were calculated as '1 kg Packaging film, low density polyethylene {GLO}| market for | Conseq, U (of project Ecoinvent 3 - consequential - unit)'.

Fodder

The red deer were not fed in Oksbøl as they are in Lille Vildmose, but as mentioned above 300 ha grass-clover game fields provided additional fodder to foraging in the wild, and also served the purpose of attracting animals to these fields where they were counted once a year between 5 and 7 a.m. to estimate the annual allowance for hunting. A census estimate was also supported by studying the feeding pressure on the game fields, reports from the staff hunters, and the weight of killed fawns. The 300 ha game fields are being re-established every 5 years in rotation, involving tillage when the soil is dry in the spring, Roundup treatment, a second tillage, sowing with mixed seeds, fertilizing with 60 kg N/ha manure and slurry from the Biogas plant in Nr. Nebel, and rolling. The fields are mowed annually for four years and re-established on the fifth. It is assumed, that the impact of establishing and maintaining the game fields are allocated 90 % to red deer and 10 % to other species. Furthermore, the fields support not only the deer that are shot in one year, but the entire population. In 2010 the red deer population was estimated at 444 animals. 358 red deer were shot, and only half of these (180) were sold to the Klosterhedens Vildt abattoir, allocating 50 % of the impact of the fields to these animals. Driving associated with establishing and maintaining the game fields was estimated at 6,000 km per year.

The nature managers at Oksbøl estimated that the deer cover 10-15 % of their annual feed need from neighbouring farmers' fields, while an expert on deer ecology in Western Jutland, Poul Hald (former vice president of 'Danmarks Naturfredningsforening') estimates 25-30%. In this study we use the mean value of 20 %. The impact of this foraging can be calculated in many ways, but it is not comparable to feeding the red deer at Lille Vildmose. When red deer forage on farmers' fields they trample crops, eat flowers, eat straw, and eat some of the final product. One farmer estimated[8] that he lost 60,000 fodder units (see calculations below) to a flock of 100 red deer. This is obviously a rough estimate, as different crops are affected differently and there are many variables.

Finally, fodder is put out to attract the deer during hunting. This is estimated as 2 t wheat and 2 t maize per year for all hunts. Transport associated with this is estimated at 140 km; $T2_{ox}$ = 6,140 km (Figure 3).

Calculations. *Extensive grass-clover production on game fields:* 300 ha/5y × (plowing+tillage+pesticide application+tillage+sowing+fertilizing+rolling) calculated as respectively 'Tillage, ploughing {CH}| processing | Conseq, U', 'Application of plant protection product, by field sprayer {CH}| processing | Conseq, U', 'Sowing {CH}| processing | Conseq, U', 'Mowing, by rotary mower {CH}| processing | Conseq, U' as rolling was estimated as mowing. Furthermore, actual mowing was carried out 4 out of 5 years (when the field was not re-established). Seeds were estimated as half grass and half clover seeds 'Grass seed, Swiss integrated production, for sowing {CH}| production | Conseq, U' and ' Clover seed, Swiss integrated production, for sowing {GLO}| market for | Conseq, U', fertilizer as 'NPK compound (NPK 15-15-15), at regional storehouse/RER Economic' and pesticides as 'Glyphosate {RER}| production | Conseq, U' since data for manure and slurry were less available.

Fodder from farmers' fields: 180 deer/100 deer per 60,000 fodder units × 20 % = 21,600 fodder units. 1 fodder unit = 1 kg wheat + 1.2 kg oat + 2.3 kg potato flour + 4 kg wheat straw. An alternative calculation would be 180 red deer × 2.5 fodder units/day (average daily need of a red deer) × 20 % × 365 days = 32,850 fodder units. The first, lower value was used for calculations of environmental impact.

Hunter and hunting

Driving associated with licence training, test shooting, buying equipment etc. was estimated as for hunters at Lille Vildmose; see calculations below. $T5_{ox}$ = 89,460 km (Figure 3).

There were five categories of red deer hunting at Oksbøl in 2010/11. Each contributed to the environmental impact of venison by the distance hunters must drive to reach Oksbøl and the distance driven during hunts. Gutting and cleaning red deer at Oksbøl before they were sent to Klosterhedens Vildt abattoir consumed energy that would otherwise be consumed at the abattoir.

Calculations. There are 5 types of hunts going on at Oksbøl:

1. *Hunting on a 900 ha leased area included*: 4 hunts permitted each year on 7 separate areas (leased for 5-y periods at the cost of 310-450,000 kr./year). Not all permits are exploited, resulting in a total number of annual hunts =16 with 30 hunters/hunt = 480 hunters transporting themselves on a 300 km roundtrip with 1.5 hunter per vehicle = 96,000 km. During hunting an estimated 250 km/hunt is covered in participating cars = 4,000 km. This totals 100,000 km driving to shoot 90 red deer. Half is estimated as passenger vehicles, half as 4WDs.

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[8] http://www.jlbr.dk/Nyheder/AlleNyheder/Kronvildtet_hoester_afgroederne_08112012.htm

2. *Entertainment hunting (free)*: two annual hunts similar to the above = 12,500 km, half passenger and half 4WDs. 40 red deer were shot.
3. *Day-lease hunts*: three per year as above = 18,750 km, shooting 70 red deer (assumed taken privately, i.e. not sent to the abattoir).
4. *Single-hunter (local)*: 100 hunters drive 20 km = 2,000 km, shooting 100 red deer (assumed all taken privately).
5. *Hunting on military areas*: four hunts per year, same as type 1 above = 25,000 km, shooting 58 red deer, of which 10 is assumed taken privately, and 48 send to Klosterhedens Vildt abattoir.

The total mileage associated with red deer send to Klosterhedens Vildt abattoir was estimated at 133,190 km for the share of red deer sold to Klosterhedens Vildt abattoir. 127,862 km relevant to the hunters' transport ($T3_{OX}$) and 5,322 km relevant to hunting ($T4_{OX}$). Half was estimated as transport by passenger cars and half as transport by 4WDs – estimated as for Lille Vildmose.

According to the park manager 180 red deer were sold Klosterhedens Vildt abattoir and a further 178 of the total kill were taken privately (60) in undesignated hunts or sold from Oksbøl's farm shop (118).

Hunter: 16×30 = 480 hunters in hunt type 1 + 2×30 = 60 hunters in hunt type 2 + 48/58×120 hunters in hunt type 3 = 639 hunters involved in the hunts leading to the shooting of the 180 red deer sold to Klosterhedens Vildt. 639 hunters drive 10×30/10 km to obtain their licence (amortized over an average of 10 years) + 639×100 km to shooting ranges + 639 × 3 × 50 km to buy equipment = 178,920 km of which 50 % is allocated to red deer hunting and the rest to other types of hunting conducted by the 639 hunters. $T5_{ox}$ = 89,460 km. Half the mileage, 44,730 km was estimated as 4WDs and 44,730 km as passenger car driving per year. Riffle bullets used in the red deer hunting where the animals were sold to Klosterhedens Vildt abattoir involved the use of an estimated (48+2)×639×2.4 g brass = 76.68 kg brass; 268.38 kg lead; 38.34 kg tungsten (calculated as copper).

4.2.3. West Jutland (data provider: Jens Henrik Jacobsen, Poul Hald)

The areas managed by the Nature Agency in mid-Western Jutland are widely scattered (Figure 6). The main areas that procured red deer for Klosterhedens Vildt abattoir were Klosterhede Plantation in the North and Gammel Ulfborg plantation in the South (red areas to the NW and SE of Holstebro in Figure 6).

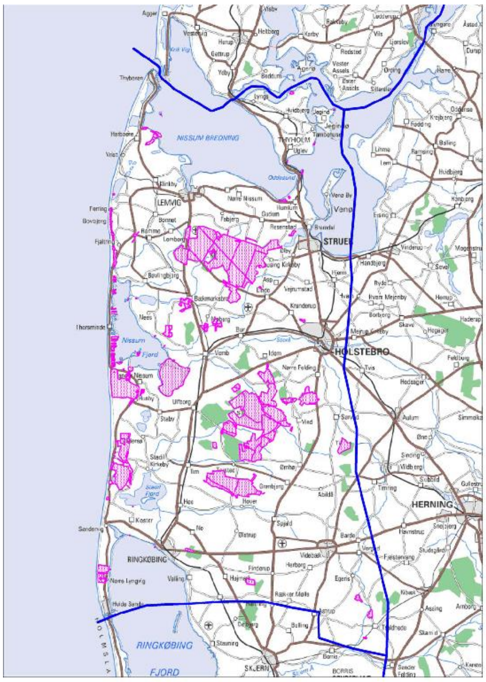


Figure 6 The pink areas inside the blue line (left) are managed by the Nature Agency of the Danish Ministry of the Environment.

Below: Beavers were first re-introduced in Denmark at Klosterhedens Plantagen in 1999 (Photo: Jysk Naturhistorisk Forening).

185 of the 252 red deer shot in Gammel Ulfborg, and 55 of the 72 red deer shot in Klosterheden were sold to Klosterhedens Vildt abattoir. A total of 324 red deer were shot at NST West of which 240 were sold to Klosterhedens Vildt abattoir in 2010/11 and 84 were taken privately, i.e. not sent to the abattoir.

Infrastructure

There is a total of 149,731 m fence at NST West protecting broadleaf cultures composed of 75 % oak and 25 % beech. An estimated 15 km 140 cm culture metal fence is put up every year and taken down after 7 years around beech cultures and after 10-12 years around oak cultures – i.e. by the time the new growth can comfortably survive the 'deer pressure'. 50 % of the environmental impact of fences is allocated to the cultures and 50 % to the red deer referring to the arguments put forward for fences at Oksbøl. In addition there is impact from 1,000 km tractor transport with post drill applied to establish/remove posts over a longer period. Regular inspection of fences required an estimated 1,000 km transport, and driving to/from work for this task an additional 800 km transport using passenger cars; driving with the purpose of counting deer was estimated at 1,200 km. Equalling a total of 3,000 km. Delivery of fence parts required 400 km transport using a small truck, while disposal of posts and scrap iron required 200 km transport using a small truck. All these mileages were allocated with 50 % to red deer hunting. Old oak posts were left in the forest.

There are 40 shooting towers in the two plantations that deliver red deer to Klosterhedens Vildt abattoir constructed from galvanized iron. They last 30 years, and weigh an estimated 40 kg each. Each year an average of 40/30 shooting tower are constructed. All shooting towers as allocated to red deer hunting. Driving tractor and trailer to replace shooting towers was estimated at 20 km, and driving to waste dump the same mileage but using a small truck. $T1_w$ =3,620 km (Figure 3).

Dead red deer were transported 12 times during 2010/11 at an average of 60 km roundtrip to the abattoir, i.e. $T6_w$ = 1,200 km using a truck with trailer (Figure 3). There was no freezer for storage at the NST West. The organic waste from hunting was left in the forest to be consumed by predators.

Calculations. *Fence materials:* 15,000 m galvanized iron fence (1.40 m) × 60 kg/100 m = 9 t iron + 1,500 iron poles × 1,5 kg = 2.25 t iron + 1500 × 4 cramps + 300 × 11 cramps = 3,300 cramps of 2 g = 18.6 kg iron, all in all 11.27 t iron calculated as: 'Chromium steel pipe {GLO}| market for | Conseq, U'. 300 oak corner poles of 0.0228 m^3 each = 6.84 m^3 oak wood calculated 'Sawnwood, hardwood, raw, air / kiln dried {RoW}| market for | Conseq, U'.

Shooting towers: 40 kg galvanized iron calculated as: 'Chromium steel pipe {GLO}| market for | Conseq, U'.

Fodder

NST West bought 25 t beets for the sustenance of the red deer sold to the abattoir in 2010/11, and hunters furthermore fed the deer with an estimated 100 t beets. The environmental impact of the 125 t beets and their delivery are allocated to the red deer sold to Klosterhedens Vildt abattoir with a ratio of 240/324 according to the actual delivery to the abattoir. The fodder is assumed to be delivered 10 times a year, being transported a distance of 50 km from producers to the drop-off sites in the forest; $T2_w$ = 370 km (Figure 3). A red deer is estimated to need 2.5 fodder units per day on an annual average, but when it enters the farmers' fields it also trample and eat reproductive structures, reducing or destroying the harvest. As for Oksbøl we assume that a flock of 100 red deer cost the farmers 60,000 fodder units per year. But even though the red deer population find feed in the forest and are fed with beets, Poul Hald estimated that the red deer cover as much 50 % of their annual need for fodder from farmers' fields near these locations.

Calculations. *Fodder:* 125 t beets × 240 / 324 = 92.6 t beets calculated as 'Fodder beets cleaned, consumption mix, at feed compound plant/NL Economic'. *Transport of fodder*: Fodder from farmers' fields: 240 red deer × 0.5 × 60,000 fodder units / 100 = 72,000 fodder units. An alternative calculation would be 240 red deer × 2,5 fodder units/day (average daily need of a red deer) × 50% of fodder need × 365 days = 109,500 fodder units. We use the first, lower value for calculations.

Hunter and hunting

There were 12 hunts engaging 20 local hunters during each hunt in 2010/11, i.e. a total of 240 hunters driving an estimated total of 780 km to/from/during the hunts. Since most hunters were local it is assumed that they participated in two hunts each. Driving for licence etc. is therefore estimated for only half the number of hunters in Oksbøl. Driving associated with licence training, test shooting, buying equipment etc. was estimated as for hunters at Lille Vildmose.

Calculations. *Hunting:* 12×780 km = 9,360 km (T3+4_W) half in Euro 3 petrol passenger cars and half in Euro 3 diesel passenger cars.

4.3 Roe deer (data provider: Wildlife manager Simon Ø. Starcke)

Brattingsborg estate situated on the Southern tip of the Island of Samsø owns 2,367 ha land used for agriculture, forestry, pork production and hunting. The hunted area is populated with roe deer, fallow deer and pheasants. In this study we only include data on the roe deer from Brattingsborg. 74 roe deer were shot in 2010/11, of which 37 were sold to Klosterhedens Vildt abattoir.

Infrastructure

A 6,500 m fence from the ocean in the West to the ocean in the East isolates the Southern tip of the island from the rest of Samsø. The metal fence is 127 cm tall and estimated to weigh 50 kg/100 m (3.25 t total). It is held by 20 iron poles per 100 m each being 138 cm long and estimated to weigh 5 kg each (6.5 t total). The total weight of this fence is thus estimated to weigh approx. 10 t. Its lifetime is estimated to be 30 years, and half the impact is allocated to roe deer and the rest to fallow deer. The annual fence allocation to roe deer is thus estimated at 170 kg. There is also a total of 3,500 m culture fence which stands for 10 years, i.e. an average of 350 m culture fence is established per year, estimated as 177 kg metal including clamps. This fence furthermore includes four 2.20 m tall 0.25 m Φ oak poles and 66 2 m tall 0.09 m Φ pressure impregnated oak poles. Calculations are described elsewhere in the report for similar fences. There are no shooting towers on the hunting grounds.

Calculations. *Cross-island fence:* 10 t iron / 30 year × 2 species deer calculated as 'Chromium steel pipe {GLO}| market for | Conseq, U'. *Culture fence:* 4 corner poles' volume = 4 × 2.2 × 3.14 × $(0,15/2)^2$ = 0.16 m3 + 66 poles' volume = 66 × 2.0 ×3.14 × $(0,09/2)^2$ = 0.84 m^3; total 1.0 m^3 wood of which the environmental impact was calculated as 'Sawnwood, hardwood, raw, air dried {RER}| market for | Conseq, U' + 177 kg 'Chromium steel pipe {GLO}| market for | Conseq, U'.

Fodder

The roe deer at Brattingsborg estate are not fed, but have open access to the estate's crop fields which for the present calculation we assume to be planted with potatoes (25 %), seed grass (25 %), rape (25 %) and grains (25 %). The roe deer cause an estimated annual loss of 22.3 t potatoes, 3.9 t grass seed, 12.0 t rape and 26.0 t grains. This loss was estimated from a declared annual economic crop loss of 125,000 D.kr. with transfer prices for these four agricultural products being respectively 1.40 kr./kg., 8.00 kr./kg., 2.60 kr./kg., and 1.20 kr./kg.

Calculations. The environmental impact was calculated according to '1 kg Potato {GLO}| market for | Conseq, U (of project Ecoinvent 3 - consequential - unit)', '1 kg Grass seed, Swiss integrated production, at farm {CH}| production | Conseq, U (of project Ecoinvent 3 - consequential - unit)', '1 kg Rape seed {DE}| production | Conseq, U (of project Ecoinvent 3 - consequential - unit)', and '1 kg Wheat grain {DE}| wheat production | Conseq, U (of project Ecoinvent 3 - consequential - unit)'.

Hunter and hunting

16 hunters drove 250 km to/from Brattingsborg during 2010/11 and took the Samsø Ferry across, and drove 6 km during each hunt, which totals 4,096 km driving. Other hunter and hunting-related impacts were calculated as before.

4.4 Fallow deer (data provider: Wildlife manager Anders H. Jørgensen)

Ørumgård near Vejle runs a deer park with Fallow deer. This is the only deliverer of fallow deer to Klosterhedens Vildt abattoir included in this study, although they only delivered 9 of the 140 fallow deer processed at Klosterhedens Vildt abattoir. The results are thus less precise than for red deer, and possibly representing the high-end values for fallow deer since they are fenced in with open access to agricultural fields. However, many fallow deer were delivered from Fyn and other long-distance locations from the abattoir where environmental impact of transport had higher impact.

Infrastructure

The 97 ha area is enclosed by 5 km fence and composed of 34 ha forest, 55 ha agriculture and 8 ha natural area. The environmental impact of the fence is

100 % allocated to the fallow deer, since it only serves to keep the deer inside the park. The fence is made from 50 × 0.15 m Φ 2.4 m tall pressure impregnated wooden posts, 575 × 0.08 Φ pressure impregnated wooden posts, 3,750 steel clamps, and 5,000 m 2.1 m tall metal fence,. Furthermore, there was 1,200 m culture fence of the same type protecting young beech and oak trees against the dense population of fallow deer. The environmental impact of this fence was allocated 50 % to the fallow deer and 50 % to the young trees. The fences have an estimated 20 year lifetime, with annual inspection estimated to require 432 km of transport.

There were 12 wooden shooting towers with a 10 year lifetime, each weighing an estimated 85 kg of which 2 kg is the metal weight of 200 screws.

Calculations. *Perimeter fence: 9.06 m^3* pressure impregnated wood calculated as 'Sawnwood, hardwood, raw, air / kiln dried {RoW}| market for | Conseq, U' plus 50 kg 'Wood preservative, inorganic salt, containing Cr {RER}| production | Conseq, U' + 10,056 kg metal fence and cramps as 'Chromium steel pipe {GLO}| market for | Conseq, U'. The culture fence was calculated in the same way, but the impact counting only as 50 %.

Fodder

The Fallow deer are fed 30 t maize and 5 t compound feed every year (impact was calculated from the recipe for 'Feinschmecher' complete feed purchased from SCA in Kolding, imported from W.E. Jameson & Son Ltd. in Masham in Northern England). The compound feed was transported 210 km by truck in England and Denmark and 650 km by ship.

Furthermore, it was assumed that the fallow deer reduced the wheat and barley harvest on the 55 ha agricultural area – to which they had open access – by 20 %. Though there are no accurate data for this, it seems likely compared with information given for red deer with access to farmers' fields elsewhere. The loss of wheat was estimated as 20 % of 27.5 ha with a normal harvest of 7 t/ha, or 38.5 t wheat loss per year. The loss of barley was estimated as 20 % of 27.5 ha with a normal harvest of 5 t/ha, or 27.5 t barley per year.

Calculations. For compound feed the exact formulation was used for the calculation of the environmental impact of its production. The environmental impact of transport was calculated as 650 km × 5 t using '1 tkm Transportation, sea ship, 10000 DWT, 50%LF, short, empty return/GLO Energy (of project Agri-footprint - gross energy allocation)' + 210 km using 'Sum total-kolonner, lastbil < 10 t, 80 load, empty return, euro2, economic alloc.'. The environmental impact of wheat was calculated according to '1 kg Wheat grain {DE}| wheat production | Conseq, U (of project Ecoinvent 3 -

consequential - unit)' and barley according to '1 kg Barley grain {DE}| barley production | Conseq, U (of project Ecoinvent 3 - consequential - unit)'.

Hunter and hunting

Fallow deer were hunted by local hunters on nine two-day hunts either with only two men or sometimes including 7-9 helpers. This is estimated as 45 hunters and helpers driving an average of 20 km, or a total of 900 km. Fallow deer were also hunted in 8-men hunts during 2 hunts with 8 men driving an estimated total of 560 km. It is assumed for fallow deer hunting that the driving for licence and test shooting only occupies 10 % of the environmental impact associated with these activities.

4.5 Wild boar *(data providers: Jacob Palsgaard Andersen and Jacob Skriver)*

Infrastructure

A 25 km additional live (electric) fence is a legal requirement associated with wild boar management in Tofte forest, the area in Lille Vildmose described in chapter 4.2.1. Where the electric fence is near public roads it stands 50 m behind the red deer fence so that the wild boar cannot be fed by tourists (risk of swine fever). The fence is constructed from two parallel 2.5 mm HT wires (heated ZnAlu galvanized steel, each weighing 3.91 kg/100 m, life time 15 years). The wire is mounted on insultimber (iron wood from Australia) posts along the 4 km public road where it is replaced every 15 years. For the remaining 21 km the HT wires were fastened to the wooden poles of the red deer fence with steel brackets weighing 10 g each. Additional driving for renewing the electric fence was estimated at 2 days per year with 50 km roundtrip per day. The live fence has two power inlets with a total power consumption of approx. 500 KWh per year. DAKA collected waste six times per year, allocating 40 km transport by truck of 1 t waste. Coldroom storage and transport to the abattoir is given in chapter 4.2.1.

Calculations. *HT wire:* 25000 m/100 m × 2 × 3.91 kg/15 y lifetime = 130.33 kg calculated as 'Chromium steel pipe {GLO}| market for | Conseq, U'. *Insultimber*: 4000 m / 5 per m /15 y lifetime = 53 posts/y, each 0.0022 m^3 =0.12 m^3 (156 kg) calculated as 'Laminated timber element, transversally prestressed, for outdoor use {GLO}| market for | Conseq, U'. *Steel brackets*: 0.01 kg × 21000 m fence × 25 major/minor posts/100 m × 2 wires = 105 kg steel calculated as 'Chromium steel pipe {GLO}| market for | Conseq, U'. (21000 m / 4 per m) × 2 wires / 15 years = 700 PVC insulators of 0.05 kg calculated as 'PVC injection moulding E'.

Fodder: The Fodder LCI data are explained in chapter 3.2.1.

Hunting

Wild boar hunting data for this report are taken from Lille Vildmose (165 of 174 wildboars were slaughtered at the abattoir), where the wild boar was hunted in mixed red deer / wild boar hunts, see chapter 4.2.1. The LCI hunting data are already presented in that chapter and the calculations further specified below.

Calculations. *Hunting*: Hunters' roundtrip driving to the rendezvous site = 5,000 km using passenger cars + 5,000 km in 4WDs relevant to wild boar ($T4_{LV}$ = 10,000 km). Driving during hunt = 300 km using passenger cars + 8.000 km hunt helpers' driving using passenger cars, totalling 8,300 km.

4.6 Overview of the environmental impact of deer and wild boar venison

The global warming potential (GWP) – one among several important environmental impacts potentials associated with deer and wild boar meat production is given in Table 2 below.

Table 2 The Global Warming Potential (GWP) is smaller for deer than for industrially produced beef, but larger for wild boar (and deer) than for industrially produced pork.

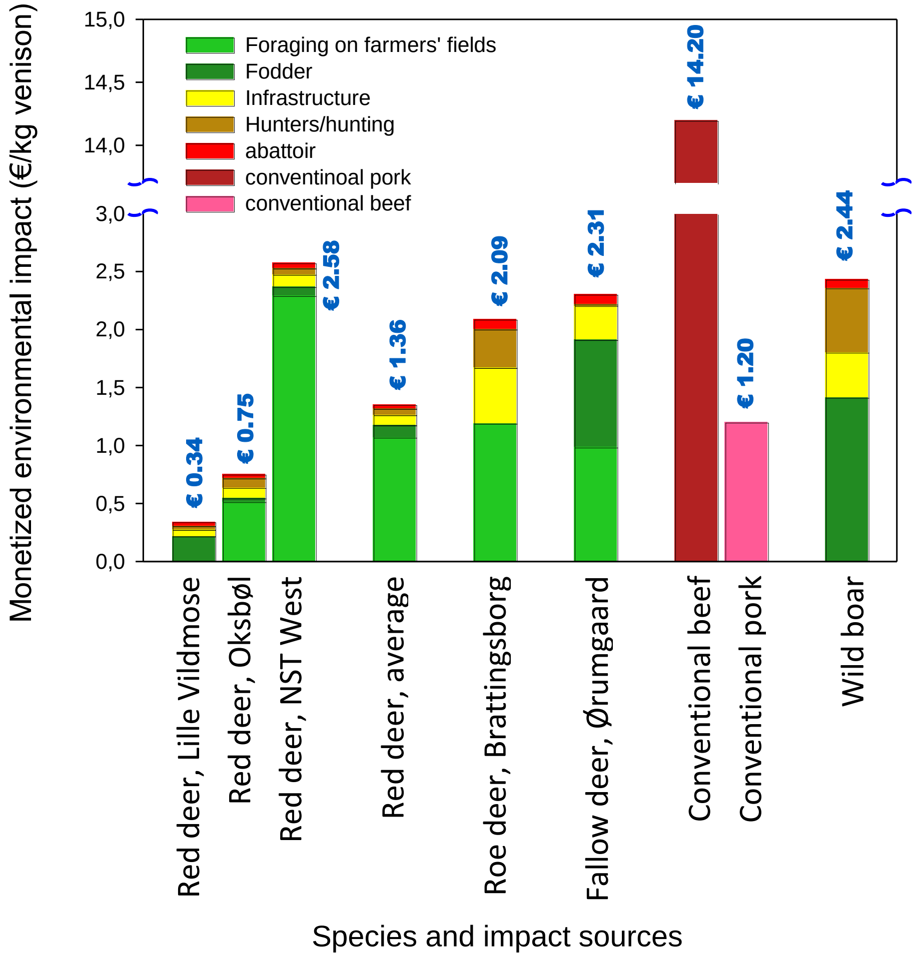
Species and hunting site		Red deer, Ll.Vild-mose	Red deer, Oks-bøl	Red deer NST West	Red deer, weighted average	Roe deer, Samsø	Fallow deer, Ørum-gaard	Beef (shop)		Pork (shop)	Wild boar
GWP (kg CO_{2eq} / kg venison)		11.3	24.4	44.8	28.6	10.5	9.8	45.9		3.3	10.2

Clearly, the impact on global warming of producing 1 kg deer venison is smaller than for producing 1 kg of beef (Cederberg et al. 2011). One reason for this is that dairy cattle emit more methane (a much stronger greenhouse gas than carbon dioxide) than deer, both in total and per kg meat (Swainson et al. 2008). Another reason is that the GWP was calculated as the marginal value in what is called consequential life cycle assessment. With other approaches, the GWP impact of beef is lower (as discussed later).

The variation of the environmental impact of venison between red deer sites in the present study indicates that there is a large dependency of the fodder, feeding on and trampling of farmers' fields, infrastructure, and hunting/hunter mileage related to the individual sites. From Table 2 it may be concluded that the GWP of consumed meat might improve if the consumers chose to eat commercially produced deer venison rather than beef (as estimated by consequential LCA), while it is not an improvement to consume commercially produced wild boar venison rather than pork.

Figure 7 illustrates the same conclusion in terms of monetized environmental impact, including all studied environmental impacts (footnote 1, p. 14). In general, the monetized environmental impact of deer and wild boar venison is largest for particle pollution and GWP, while human toxicity (non-carcinogenic) and area use also contribute significantly, while the rest of the impact categories contribute much less (data not shown). The largest contribution to the monetized environmental impact comes from the feed/fodder (Figure 7).

Figure 7 Monitized values of all the studied environmental impacts of red deer (from three sites), roe deer, fallow deer, wild boar, and commercially produced beef and pork. The individual contributions of feeding on farmers' fields, fodder, infrastructure, hunter/hunting and abattoir are shown using individual colour codes.



4.7 Mallard *(data providers: Frederik Stadel Thomsen and Niels Chr. Nielsen[9])*

4,000 mallards were supplied to Klosterhedens Vildt abattoir from Frijsenborg during the 2010 hunting season. The mallards were supplied to Frijsenborg by *Bakkegårdens Vildtopdræt* (Figure 8) from where they were put out in constructed lakes.

Figure 8 The mallards at Frijsenborg originated from Bakkegårdens Vildtopdræt owned by Frederik Stadel Thomsen (photo) north of the city of Skive who produces 125,000 mallard ducklings a year, and a total of 300,000 duckling eggs from a population of 7,000 parent ducks. Photo: Henrik Saxe.

Infrastructure

Mallard eggs are produced at Bakkegårdens Vildtopdræt from 20 February to 15 June, and washed and hatched. It takes 28 days to hatch duckling eggs, after which they spend 3 weeks in stables heated by gas at a cost of 0.50 DKr. per duckling equivalent with 0.2 m^3 natural gas per duckling. A production of 125,000 ducklings requires 30 t of hay/year for bedding.

Ducklings were transported 85 km from Bakkegårdens Vildtopdræt to Frijsenborg in two batches using a small van or equivalent.

20 lakes were constructed at Frijsenborg over 40 years, where the lakes are estimated to have a lifetime of 50 years. The lakes are typically constructed by establishing dams, where 200 m dam results in 8 ha lake

[9] Gamekeeper at Frijsenborg, now retired.

(average lake size), by working an excavator for 20 hours. As a rule there is only 1 mallard per 150 m^2 of lake to guard against water pollution. Over the life time of a lake, an 8 ha lake is estimated to accommodate 25,000 ducks. An excavator is assumed to move 30 m^3 soil/h.

The Frijsenborg lakes accommodate 4,000 new mallards every year.

Calculations. *Washing eggs*: 4,467 eggs (90 % hatch) × 0.6 l water = 2,680 l warm water + 4,467 × 0,03 g detergent = 149 g detergent was calculated as '1 kg Drinking water, water purification treatment, production mix, at plant, from groundwater RER S (of project ELCD)' and '1 kg Soap {RER}| production | Conseq, U (of project Ecoinvent 3 - consequential - unit)'. Electricity for hatching machines was estimated at 800 KWh for 28 days hatching period for 4,020 mallard eggs using Funki 8c/6 hatching machines from Danki, and the environmental impact was calculated as 'Electricity, medium voltage {DK}| market for | Conseq, U'. Natural gas was calculated as 'Natural gas, low pressure {CH}| market for | Conseq, U (of project Ecoinvent 3 - consequential - unit)' and hay as 'Swiss integrated production, intensive {CH}| production | Conseq, U, Ecoinvent 3'.
The environmental impact of constructing 200 m dam was calculated by 'Excavation of 1 m^3: Excavation, hydraulic digger {RER}| processing | Alloc Def, U'. 20 h ×30 m^3/h = 600 m^3 soil excavated + driving 3 days of 30 km roundtrip each day to the lake.

Fodder

The mallards in Frijsenborg's lakes are put out during May-June, fed for 105 days with 50 g whole wheat grains per day and per mallard, and hunted for 4 months from 1 September to 31 December.

The ducklings raised at Bakkegårdens Vildtopdræt come from parent mallards that consume 80 g 'red duck' complete feed from DLG from 1 February to 15 June (135 days) and whole wheat grains the rest of the year (230 days). Parent mallards survive as parent ducks for up to 3 years, after which they are sold for hunting. Each mallard produce 40 eggs per year, of which 90 % hatch. It therefore takes 112 parent mallards to produce 4,020 ducklings. The ducklings consume 250 g 'yellow duck' complete feed from DLG the first 10 days of their life, and 500 g 'green duck' the next 11 days, until they are sold.

The complete feed and whole grain wheat was assumed to arrive at Frijsenborg by truck covering a distance of 75 km roundtrip. Whole wheat is distributed at Frijsenborg 15 times from 1 June to 15 September being transported 20 km each time.

Calculations. Fodder at Bakkegårdens Vildtopdræt: Ducklings (2 % die within 5 days): The environmental impact of their complete duck and duckling feed (the formulae were confidentially obtained from DLG bird feed optimization unit) was calculated as the environmental impact of 4,020 × 0.25 kg ‘yellow duck’ + 4,000 x 0.5 kg ‘green duck’ for ducklings over 10 days + 11 days (3 weeks), and for parent mallards as 135 (days) × 112 × 0.08 kg ‘red duck’ = 1,210 kg ‘red duck’ + 230 (days) × 112 × 0.08 kg = 2,061 kg whole grain wheat calculated as ‘Wheat grain, consumption mix, at feed compound plant/IE Economic’. Fodder for maturing mallards at Frijsenborg consisted of 105 days × 0,08 kg × 4000 mallards = 33,600 kg whole grain wheat.

Hunter and hunting

Of the 4,000 mallards delivered to Frijsenborg, 3,082 (77 %) were shot and transported to Klosterhedens Vildt, while the rest escaped in nature to survive on their own and migrate to Western Jutland, Sealand, and abroad maybe even as far as Siberia, and were thus lost to the commercial production system at Frijsenborg. This means that the environmental impact of infrastructure and feed for 4,000 mallards were allocated to the mallards shot at Frijsenborg and sold to Klosterhedens Vildt abattoir. This increases the environmental impact induced by infrastructure and feed by a factor 1.30 (4,000/3,082).

There were five annual hunts at Frijsenborg in 2010 where up to 500 mallards were shot during each hunt, and four hunts shooting up to 175 mallards. Ten hunters participated in each hunt, arriving in 8 cars. In one hunt the average distance from home to Frijsenborg was estimated at 500 km roundtrip, in the other eight the roundtrip distance for local hunters averaged 50 km. On top of this come resources needed for hunting assistants.

Hunter’s preparations are calculated as for red deer. Waterfowl ammunition weighs 32 g per cartridge, and at least two shots are assumed fired per killed mallard. Lead is not permitted; the cartridge material is steel.

Calculations. Hunter’s cars (50 % 4WD) drive 8 × 500 km × 1 (hunt)+ 8 × 50 km × 8 (hunts) = 7,200 km. Local driving for hunting on the Frijsenborg Estate was estimated as 9 (hunts) × 15 km = 135 km in a minibus.
Hunter: 90 hunters drive 10×30/10 km to obtain their licence + 90×100 km to shooting ranges + 90 × 3 × 50 km to buy equipment = a total of 36,000 km estimated as 18,000 km 4WDs and 18,000 km passenger cars per year. Only half of these mileages were allocated to mallard hunting, and the rest to other types of hunting conducted by the same 90 hunters. Ammunition: 3,082 mallards × 2 shots × 32 g = 265 kg steel pellets in cartridges (the remaining parts of cartridges, powder, 8 g plastic, and 3 g sheet metal have insignificant impact).

4.8 Pheasant *(data provider: Niels Chr. Nielsen)*

Only 40 % of the pheasants at Frijsenborg estate are shot during the hunts, the 30 % are taken by neighbours and predators, and 30 % survive until the next season or longer and tend to migrate.

Figure 9 The pheasants from Frijsenborg estate roam the fields of Frijsenborg and the neighbourhood. Photo: Henrik Saxe

Infrastructure

600 parent pheasants were caught in the forests in early 2010 and put in aviaries. Eggs were collected, hatched and chickens raised in wooden sheds with electric lighting and a mother hen in each shed. When ready, the young birds advance to small aviaries outside the sheds, and at an age of 6 weeks they are set free in the forest.

Calculations. Shed and aviary wood per 100 chickens is estimated at 2.6 m^3 wood 'Sawnwood, hardwood, raw, air dried {RER}| market for | Conseq, U' and 10 kg metal 'Chromium steel pipe {GLO}| market for | Conseq, U' with a 20 year lifetime of this infrastructure. Electricity for lighting and electric fences is estimated at 1,000 KWh for all pheasants. Electricity for hatching is estimated at 1,600 KWh.

Fodder

8,000 pheasants were raised by Frijsenborg estate during 2010. However, to day pheasants are no longer raised at Frijsenborg estate anymore. During the 6 weeks it took for eggs to turn into young birds, the chickens were fed 1.5 kg complete feed each or a total of 12 t complete feed during 2010. A generic recipe for raising 100 pheasants is given by Jægernes Magasin (https://jaegernesmagasin.dk/artikler/fasan-udsaetning-koster). According to this the 8,000 pheasants were fed 70 g/day totalling 31.4 t complete feed, 37.6 t wheat, and 25.1 t maize after they are set free. This information must be evaluated relative to the information from Frijsenborg that pheasants were fed only 40 g wheat per day or 48 t wheat from 1 July until they were set free 1 December when hunting commenced.

Any medication must (in principle) be prescribed by a veterinarian, and commercial feed may only contain coccidiostats and other medication if produced at certified factories and prescribed by veterinarians. Pheasant feed from DLG contained 99 ppm of the coccidiostat Lasalocid. Potential problems with coccidiostats, antibiotics, lead etc. are not considered for pheasant, mallard or any other species in this report, but could possibly add further to the environmental impact of venison; however, neither are these taken into account in the calculation of environmental impact of industrial meat.

Calculations. The environmental impact of 12 t +31.4 t complete feed was calculated as 'yellow duck', and 37.6 t wheat and 25.2 t maize as 'Wheat grain {DE}| wheat production | Conseq, U' and 'Maize grain, Swiss integrated production {CH}| production | Conseq, U'.

Hunter and hunting

Six hunts with 12 participating hunters in each were arranged during 2010 shooting an average of 400 pheasants per hunt. Furthermore there were four hunts with 12 hunters shooting an average of 200 pheasants. This totals 3,200 pheasants shot in 2010. It is assumed that for one hunt eight passenger cars drove 500 km, and for each of the other nine hunts eight passenger cars drove 50 km, giving a total transport to hunts of 7,600 km. Local helpers and retrievers added an estimated 640 km to this mileage.

4.9 Overview of the environmental impact of mallard and pheasant venison

The global warming potential (GWP) for the mallard and pheasant meat is given in Table 3 below.

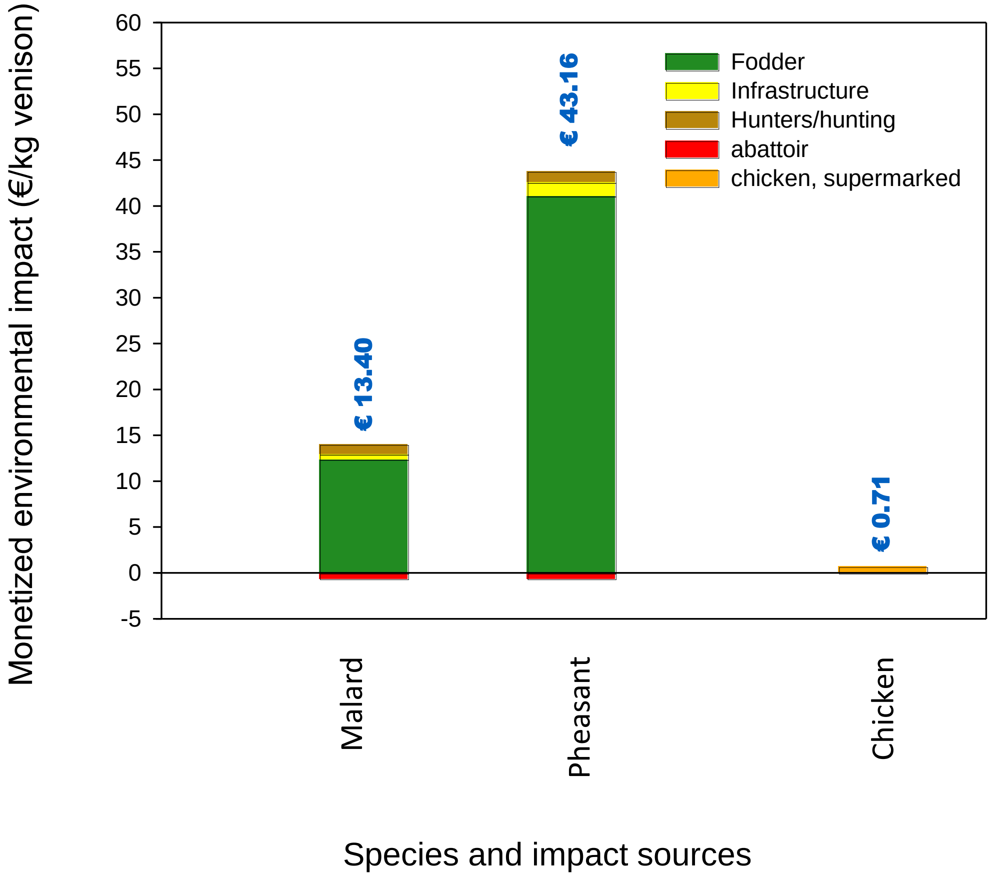
Table 3. The Global Warming Potential (GWP) is much larger for mallard and pheasant meat than for industrially produced chicken.

Species and hunting site		Mallard, Frijsenborg	Pheasant, Frijsenborg		Chicken (shop)
GWP (kg CO_{2eq} /kg venison)		34.9	145.2		3.1

Clearly, the impact on global warming of producing 1 kg mallard or pheasant meat is far larger than for producing 1 kg of chicken; nearly 11 times larger for mallard, and 47 times for pheasant. From Table 3 it may be concluded that the GWP of consumed meat will improve significantly if the consumers stay with eating commercially produced chicken rather than mallard or pheasant.

Figure 10 illustrates the same conclusion in terms of monetized environmental impact, including all (footnote 1, P. 14) studied environmental impacts. In general, the monetized environmental impact of mallard and pheasant is largest for particle pollution and GWP, while human toxicity (non-carcinogenic) and area use (for growing feed) also contribute significantly, while the rest of the impact categories contribute much less.

Figure 10 Monetized values of all the studied environmental impacts of mallard, pheasant and commercially produced chicken (orange). The individual contributions of fodder (dark green), infrastructure (yellow), hunter/hunting (brown) and abattoir (red) are shown using individual colour codes.



There is so much combustible waste from mallard and in particular from pheasant that the negative environmental impact of the abattoir is more than countered by the positive contribution by combustion of this waste at the waste plant (substituting fuel elsewhere in the system). To the extent that the waste is not combusted, it is transformed and reused as products that substitute other products, also turning the environmental impact of the abattoir into a "good cause" for the overall environment as further discussed in the subsection on waste in section 4.10 below.

4.10 Klosterhedens Vildt abattoir

Klosterhedens Vildt abattoir today supplies a major part of Danish commercial venison: 65 % of all red deer, 70 % of wild boar, 20 % of the roe deer, 50 %

of the mallards and 10 % of all pheasants, and some fallow deer. Kivan Food Ltd. on Zealand delivers the major part of the remainder and minor producers delivers the rest (approx. 5-10 %). In this section the environmental impact of processing venison at Klosterhedens Vildt is estimated.

Materials

Red deer steaks are vacuum-packed in plastic bags inside 24 g cardboard boxes with a 0.1 g plastic window to show the content of the 300 g meat in the package. Assuming all red deer was sold in these (or alternatives with similar environmental impact), the 25,465 kg red deer meat produced in 2010/11 required 84,883 packages.

The environmental impact of the total use at the abattoir of an estimated 7 t of general cardboard for boxes and more, and 100 kg of vacuum plastic bags and gloves are allocated according to the meat weight of the six species given in Table 1.

Calculations. *Red deer meat packaging:* The environmental impact of 84,883 boxes × 0,024 kg = 2,037 kg boxes was calculated as '1 kg Liquid packaging board container {RER}| production | Conseq, U (of project Ecoinvent 3 - consequential - unit)'. Cardboard was calculated as ' 1 kg Carton board box production, with offset printing {GLO}| market for | Conseq, U (of project Ecoinvent 3 - consequential - unit)' and plastic as '1 kg Packaging film, low density polyethylene {GLO}| market for | Conseq, U (of project Ecoinvent 3 - consequential - unit)'.

Waste

The environmental impact of waste from deer and wild boar, which is roughly allocated to each species according to the final meat weight, totalled 25,695 kg. A percentage of mallards and pheasants are discarded due to its content and position of pellets. Waste from birds totalled 13,246 kg, which is allocated between mallard and pheasant as 1:4, though the final meat product weight is nearly equal. The environmental impact of waste is ascribed to transport by DAKA for incineration and to the incineration itself. Transport (tkm) was allocated to species according to weight, and DAKA collected waste twice a week for 26 weeks. For red deer for example the 2,080 km transport (waste was collected twice a week for 26 weeks, distance 40 km) was 67.3 % of the overall waste, and furthermore it is assumed that the abattoir only filled 10 %

of the waste lorry, resulting in an effective transport distance of only 104 km + another 40 km to the end user (T8, Figure 3). But what counts in terms of environmental impact (which for T8 is very small in the overall perspective of red deer venison production) is the tonnage, i.e. tkm. And what really counts in terms of environmental impact of waste is the assumed incineration (abattoir waste category 1, used e.g. by Aalborg Portland ltd.), though today incineration is not the only pathway for abattoir waste. Today DAKA also produce biodiesel (waste category 1 and 2 from fat), fertilizer (waste category 2) and hides. However, in this study, for simplification it was assumed that all waste was incinerated for electricity production. The positive environmental impact of this electricity production is estimated to be 1.5 times larger than the negative environmental impact of driving the waste for incineration. Today Klosterhedens Vildt also delivers 3.7 t meat and bone waste to Ree Park Safari where it is used for feeding predatory park animals. This also reduces the environmental impact as it substitutes formulated feed pills imported to the Safari Park from Holland, though it misses the opportunity of electricity production.

Klosterhedens Vildt abattoir produces 165,000 l process water per year which is collected by Lemvig Biogas 15 km from the abattoir. The content of organic matter is so low (0.15 %) that it only generates 0.5 l biogas, adding an insignificant positive gain. Process water treatment does not contribute significantly to the environmental impact of the abattoir.

Calculations. *Driving by DAKA:* Environmental impact calculated according to 'Sum total-kolonner, lastbil < 10 t, 80 load, empty return, euro2, economic alloc.'. *Incineration:* The environmental (positive) impact of incineration was calculated according to '1 kg _92 Waste treatment, Incineration of waste, Food, DK (of project EU & DK Input Output Database)'. The impact of waste water treatment was calculated according to '1 kg_105 Waste treatment, Waste water treatment, food, DK', and is due to electricity, heat and water consumption.

Energy consumption

There is a single cold room operating at -18° C, four cold rooms at 4° C, two cold rooms at 7° C, and two cold rooms at 12° C. Furthermore there is energy consumption associated with slaughtering and office. The total energy consumption 2010/11 was 30,110 KWh. The environmental impact of this energy consumption is allocated roughly according to produced meat weight of each species.

Calculations. The impact of electricity was calculated according to 'Electricity, medium voltage {DK}| market for | Alloc Def, U'.

Transport

Veterinary control was carried out 7 days a week for 9 weeks, and 8 times more over 4 weeks, resulting in 80 visits where the veterinarian drove 10 km for each or 800 km/year. Four butchers drove three passenger cars 34 km for 55 days per year, a total of 5,610 km/year. Four helpers drove 8 km 76 days/year totalling 2,432 km/year. The director drove 90 km 130 times per year = 11,700 km/year and a book keeper 8 km 130 times per year = 1,040 km. Total transport of personnel = 21,582 km using passenger vehicles.

Furthermore, meat products were transported to supermarkets and restaurants all over Denmark and the waste from there to waste dumps (T7, Figure 3). Products from deer and wild boar are assumed to be transported an average of 300 km by van, while birds are assumed to be transported an average of 150 km.

5. Discussion and conclusions

The environmental impact of commercially available venison produced in Denmark has not been studied before. The findings in this report offered several new insights discussed below.

5.1 Transport

First of all it was surprising that there is so much transport involved in the production of venison: Hunters driving to hunts, hunters driving to buy equipment and acquire their licence, and test-shoot their weapons every season; there is transport of fodder, transport of carcasses, transport of produce and transport of waste; transport of supplies for the infrastructure, fences and shooting towers; and driving to check and repair fences after storms. For the 180 red deer originating from Oksbøl there was about 240,000 km of transport involved. But in terms of environmental impact, transport only makes up a minor part of the overall impact associated with the commercial production of venison. Transport is mostly associated with the hunter/hunting including helpers and retrievers (brown colour in Figure 7 and Figure 10).

5.2 Fodder and feeding/trampling on farmers’ fields

The main environmental impact of commercially produced venison at Klosterhedens Vildt abattoir is what the animals consume, either when fed (as e.g. red deer and wild boar at Lille Vildmose – dark green colour in Figure 7 and Figure 10) and/or when trampling and feeding on farmers’ fields (light green colour in Figure 7 and Figure 10). The environmental impact of fodder and/or feeding on farmers’ fields is from 1.3 (roe deer) to 20 (pheasant) times larger than the sum of all other impacts associated with venison production (green colours in Figure 7 and 10). For wild boar it is 1.4 times, for fallow deer 4.9 times, for red deer 6.7 times and for mallard 12.3 times larger.

The trampling/feeding on farmers’ fields is a difficult component to estimate, and at the same time in this study it was found to be the most important component in the environmental impact of commercially produced venison. For red deer it averaged more than 90 % of what the deer consumed, and for fallow deer it was about 50 %, while for confined animals, wild boars and red deer at Lille Vildmose, mallards and pheasants it was zero. Farmer, hunters and nature managers often have opposing interests in the size of wild life populations, though of course farmers may also enjoy hunting, and sometimes try to lure wildlife onto their fields for this purpose.

One conclusion from the above is that wild game and raised game most likely have very similar environmental footprints. The distinction between the two is difficult to make; the transition is gradual. In fact very few wild game individuals are truly wild – they are most likely living off agricultural crops one way or another.

5.3 Commercial vs. privately taken venison

This report investigated only commercially produced venison in order to compare the environmental impact hereof with commercially produced meat from cow, pig and chicken.

Some may assume that private hunting has a far smaller environmental footprint than the commercially produced venison described in this report. However, since fodder and feeding/trampling farmers' fields or hunting fowl that was raised and fed with the purpose of hunting, is typically a major part of the environmental impact of nearly all hunted wildlife, even the privately taken venison is expected to have a surprisingly high environmental footprint. Furthermore, private hunting often results in a lower yield than commercial hunting where 3-4 large animals may be bagged in a single two-man rifle hunt, or 30-40 birds in a single battue, while many hunters return empty handed from private hunts, thus driving many more kilometres per kill.

If wildlife is not killed by hunters, it will either migrate, be taken by predators, or the population may grow above the carrying capacity of the landscape (and feeding) and the populations risk collapse by starvation. With increased wildlife density, mortality increases. But of all mammals and bird species that breed and thrive in Denmark, the 90 % not-hunted species manage perfectly well to stay within sustainable population sizes *without* requiring hunting for regulation.

5.4 Representativeness

How well do the results in this report represent commercial venison produced in Denmark? Klosterhedens Vildt abattoir produces approximately major percentage of Danish venison sold in Danish shops and restaurants, and by weight this is mostly red deer and wild boar. Kivan Food Ltd. produces similar amount, but this is mostly fowl. The rest is supplied by minor suppliers.

In Denmark there are 50 species of mammals and 300 bird species that are in principle protected. But for 10 mammal species and 33 bird species hunting is permitted for some months every year. Annual statistics are prepared for all wildlife hunted and killed (Asferg 2014). In recent years the annual hunting yield has been around 2.6 million 'wild' animals. Roe deer, hare, fox, pheasant, wood pigeon and mallard are the most frequently hunted. In 2013/14 (2010/11), 122,400 (128,200) roe deer, 10,300 (7,400) red deer, 8.300 (6,000) fallow deer, 61,700 (61,300) hares and wild rabbits, 27,800 (39,300) foxes, 700,600 (721,400) pheasants, 241,600 (299,500) wood pigeons and 469,000 (485,400) mallards were shot in Denmark (Asferg 2014, Asferg 2011).

According to the above numbers and to Table 1 Klosterhedens Vildt abattoir produces 10 % of all red deer shot in Denmark during the 2010/11 season[10], 2 % of the fallow deer, 0.002 % of the roe deer (nearly all taken privately, i.e. not sent to the abattoir), nearly all wild boar, 0.06 % of the mallards (nearly all taken privately) and 0.2 % of the pheasants (nearly all taken privately). Even though Kivan Ltd. produces most of the Danish bird venison, breeding and feeding of mallards and pheasants is more or less the same as for birds delivered to Klosterhedens Vildt abattoir. In conclusion, the representativeness

[10] This must not be confused with the share of the commerciallly available venison that Klosterhedens Vilds abattoir produces. See section 4.10.

of the environmental impact numbers are reasonable representative for commercial Danish venison, but less representative of the overall hunting yield in Denmark, where most is taken by the hunters themselves. But according to section 5.3, the environmental impact may not be much smaller for game taken by the private hunter compared to game sold for commercial production for the Danish consumer. Venison sold by private hunters to consumers is legally a grey zone.

5.5 Positive and negative impacts of game and hunting - perspectives

Within the framework of this report it was not possible to quantify the positive impacts associated with the immaterial value of the "joy of hunting" or the importance of game in maintaining valuable biotopes. In the monetized accounting of the negative environmental impacts, the "joy of hunting" and biotope maintenance could be a positive counterweight. Some nature managers believe that hunting is necessary to keep a balanced stock of wildlife. But without hunting there would simply be another natural balance of wild life species. Furthermore, parts of the public may also consider hunting to be a problem for a peaceful walk, hike or bike trip in the forests. And some people have an ethical problem with hunting/killing wildlife, particularly when hunting is a 'sport' rather than a way to obtain food.

The largest environmental impact of commercially produced venison is caused by *feed/fodder* consumption (Figure 7 and Figure 10). The savings envisioned for wild animals in terms of them being sustained by wild flora, foraging on areas which are not farmed turned out to be a false pretence – and more so with some species than others. The production of venison from mallard and pheasant were proven to be respectively 19 and 61 times more harmful to the overall environment than chicken meat; production of wild boar venison was 3 times more harmful to the environment than pork; but production of deer meat was possibly less harmful to the environment than production of beef – red deer 10 %, roe deer 15 % and fallow deer 16 %. These relative numbers, however, must be taken with some care, since they varied with local conditions of feeding and foraging on farmers' fields. Another reason to treat the deer vs. beef comparison with care is that the impact numbers for beef were taken from a consequential life cycle assessment. Numbers for the environmental impact of beef vary according to calculation methods and applied metrics in the range from about 10 Kg CO_2eq to about 50 CO_2eq for the global warming potential associated with the production of 1 kg of beef (Persson et al. 2015). With numbers in the low end of this range, commercially produced beef may in fact have *lower* overall environmental impact than red deer meat, and is *on par* with roe deer and fallow deer meat. And compared with pork (Figure 7), another alternative to deer meat, the latter has a significantly *higher* overall environmental impact and GSP; and compared with chicken (Figure 10) an even higher impact.

The bottom line is that there is *little or no environmental advantage* in choosing any type venison over industrial meat, mostly because there are *little or no savings* on feed for wild animals compared with domestic animals, sometimes on the contrary – and extensively so. This is because of the *inefficiency of most venison production*. Feeding is inefficient because it is not targeted, and from a production point of view it is therefore often '*wasted'* when other wild life consumes it, or it is left to *decompose* in nature. 'Harvesting' the animals is also inefficient as many of the well-fed animals *escape* out of the production system, as most clearly seen with mallards and pheasants, and as hunters compared with butchers transport themselves over long distances, sometimes without taking home any game at all.

The damage to *farmers' fields* and foraging on those fields has never been precisely accounted for, and may be underestimated by wildlife managers and hunters who may have an interest in underestimations. Farmers may condone wildlife foraging or may even try to attract wildlife by putting out fodder if they want to hunt wildlife themselves. If farmers could agree that they would prefer to have less wildlife feeding off their fields, the Nature Agency could possibly (at a cost) supply more feed or plant fields inside forests to keep the deer in the forests and natural areas. Furthermore, the nature agency could put up more fences if they want to protect farmers' fields and traffic against deer (as in Jægersborg Dyrehave North of Copenhagen), and protect the deer against unwanted hunting, rather than only putting up fences to protect new plantations against deer browsing. These are charged questions as input to a currently ongoing debate on wildlife management and hunting in Denmark for which this report hopefully contributes with new knowledge.

5.6 Not enough venison to satisfy the New Nordic Diet

The existing populations of hunted wildlife in Denmark yielding approximately 1.4 g venison per Dane per day (Danish Academy of Hunting, 2014) only satisfies a quarter of the recommended venison intake recommended for the New Nordic Diet (Meyer et al. 2011), even if the goods were evenly shared among Danish consumers and all were following the recommendations. If the Danish venison production was to be increased, it would take significantly more feeding and fencing. And in that scenario it is a big question whether the game could still be considered as free ranging wildlife, both in terms of animal welfare, human health, taste and environmental impact.

Animal welfare is also part of the ongoing debate on venison *versus* industrial meat. Meat from mallard and pheasant is extremely inefficient in environmental terms – it has considerably high environmental impacts per kg meat compared with chicken meat. However, both mallards and pheasants live at least a few months of their lives in nature, sometimes even years before they are shot. In contrast, commercial chicken meat comes from birds that typically never saw daylight or truly natural living conditions. Deer and wild boar may also be considered experiencing superior animal welfare compared with cows and pigs in conventional Danish animal production.

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References

Asferg, T. 2011. Vildtudbyttestatistik for jagtsæsonen 2010/11. Institut for Bioscience, Århus Institut. Notat fra DCE – Nationalt Center for Miljø og Energi. http://dce.au.dk/fileadmin/dmu.au.dk/Vildtudbyttestatisik_2010_11.pdf.

Asferg T. 2014. Vildtudbytte for jagtsæsonen 2013/14. Notat fra DCE – Nationalt Center for Miljø og Energi. Institut for Bioscience, Århus universitet. http://dce.au.dk/fileadmin/dce.au.dk/Udgivelser/Notater_2014/Vildtudbyttestatistik_2013_14.pdf.

Bregnballe T, Asferg T, Christensen TK, Clausager I, Clausen P. 2003. Vildtarter og jagttider. http://www2.dmu.dk/1_viden/2_publikationer/3_miljobib/rapporter/mb03.pdf.

Cederberg C, Persson UM, Neovius K, Molander S, Clift R. 2011. Including carbon emissions from deforestation in the carbon footprint of Brazilian beef. Environ Sci Technol 45:1773–9.

Christensen TK et al. 2013. Jagttidsrevision 2014. Vurdering af jagtens bæredygtighed i forhold til gældende jagttider. Videnskabelig rapport fra DCE – Nationalt Center for Miljø og Energi. Rapport nr. 66. Institut for Bioscience, Aarhus Universitet. http://dce2.au.dk/pub/SR66.pdf.

Cordain L, Watkins BA, Florant GL et al. 2002. Fatty acid analysis of wild ruminant tissues: evolutionary implications for reducing diet-related chronic disease. European Journal of Clinical Nutrition 56(3):181-91. http://www.ncbi.nlm.nih.gov/pubmed/11960292.

Danish Academy of Hunting. 2014. Personal communication with director Niels Kanstrup.

Jacobsen L-B, Jensen FS, Bakhtiari F, Thorsen BJ. 2014. Friluftslivets nationaløkonomiske fodaftryk. IFRO report 229. http://ifro.ku.dk/aktuelt/friluftsliv/.

Kanstrup N. 2009. Bly i fuglevildt i Danmark – indhold og kilder. Teknisk rapport 0904-01. Dansk Jagtakademi. www.danskjagtakademi.dk.

Kanstrup N, Madsen P, Stenkjær K, Buttenschøn RM, Jensen A. 2014. Kronvildt på Sjælland. Resultaterne af tre års praksisorienteret forskning og forvaltning. IGN Rapport, Copenhagen University. ISBN 978-87-7903-6;

http://ign.ku.dk/formidling/publikationer/rapporter/filer-2015/kronvildt-sjaelland-978-87-7903-682-6.pdf.

Meyer C et al. 2011. Grundlaget for Ny Nordisk Hverdagsmad – OPUS WP1. http://foodoflife.ku.dk/opus/media/docs/pdfer/Grundlag-for-Ny-Nordisk-Hverdagsmad.pdf/.

Persson UM, Johansson DJA, Cederberg C, Hedenus F, Bryngelsson D. 2015. Climate metrics and the carbon footprint of livestock products: where's the beef? Environmental Research letters 10. Doi:10.1088/1748-9326/10/3/034005.

Petersen MR. 1998. Botanisk analyse af vomprøver af rådyr (*Capreolus capreolus*) fortrinsvis fra Borris Hede. Specialerapport, Botanisk Institut, Økologisk afdeling, Københavns Universitet.

Rio Declaration. 1992. http://www.unep.org/Documents.Multilingual/Default.asp?documentid=78&articleid=1163

Saxe H. 2014. The New Nordic Diet is an effective tool in environmental protection – reducing the associated socio-economic cost of diets. The American Journal of Clinical Nutrition 99:1117-1124.

Saxe H, Larsen TM, Mogensen L. 2013. Two healthy Nordic diets reduce the impact on climatic change of eating and drinking. Climatic Change 116: 249-262. http://link.springer.com/article/10.1007%2Fs10584-012-0495-4#page-1.

Steinfeld H et al. 2006. Livestock's long shadow. FAO. ftp://ftp.fao.org/docrep/fao/010/A0701E/A0701E00.pdf.

Swainson NM, Hoskin SO, Clark H, Pinares-Patiño CS, Brookes IM. 2008. Comparative methane emissions from cattle, red deer and sheep. Proceedings of the New Zealand Society of Animal Production 68:59-62.

Weidema BP. 2009. Using the budget constraint to monetarise impact assessment results. Ecol Econ68:1591–1598.